Laboratori d'Arqueologia Quantitativa

J.A. Barceló

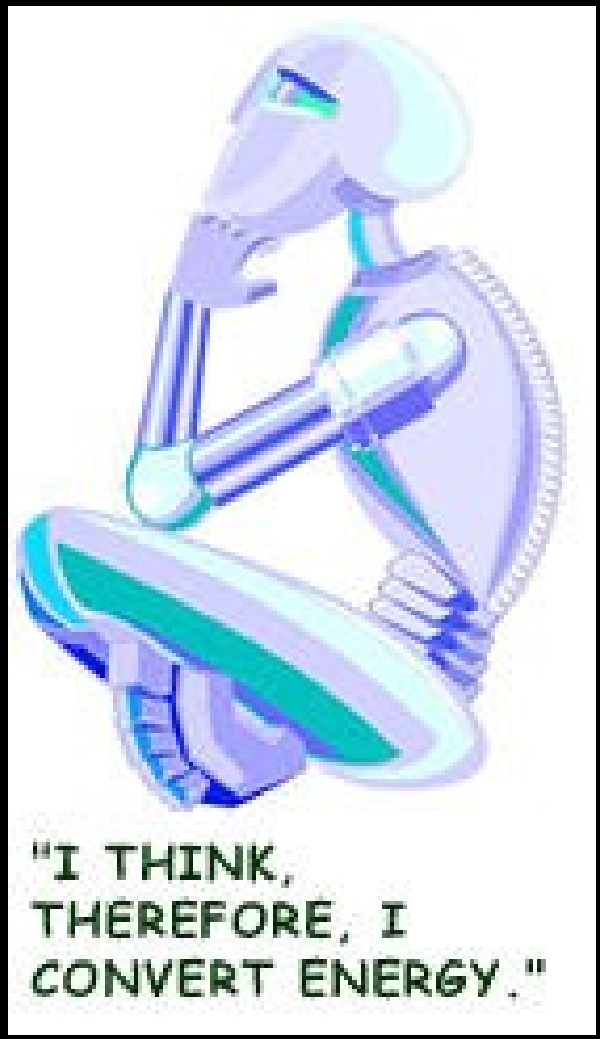
Is it possible to design a machine to do archaeology?

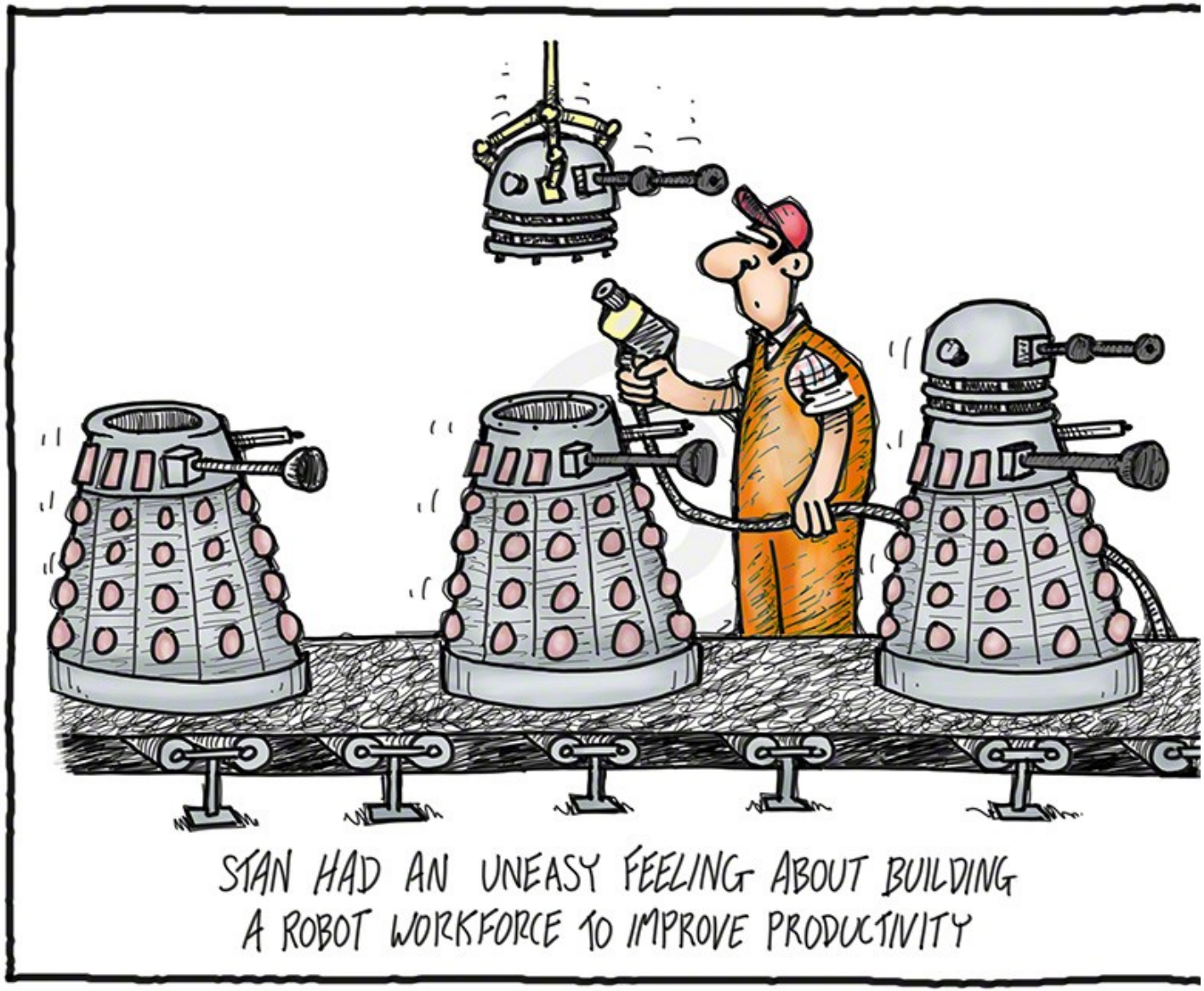
Will this machine be capable of acting like a scientist?

Will this machine be capable of understanding how humans act, or how humans think they acted in the Past?

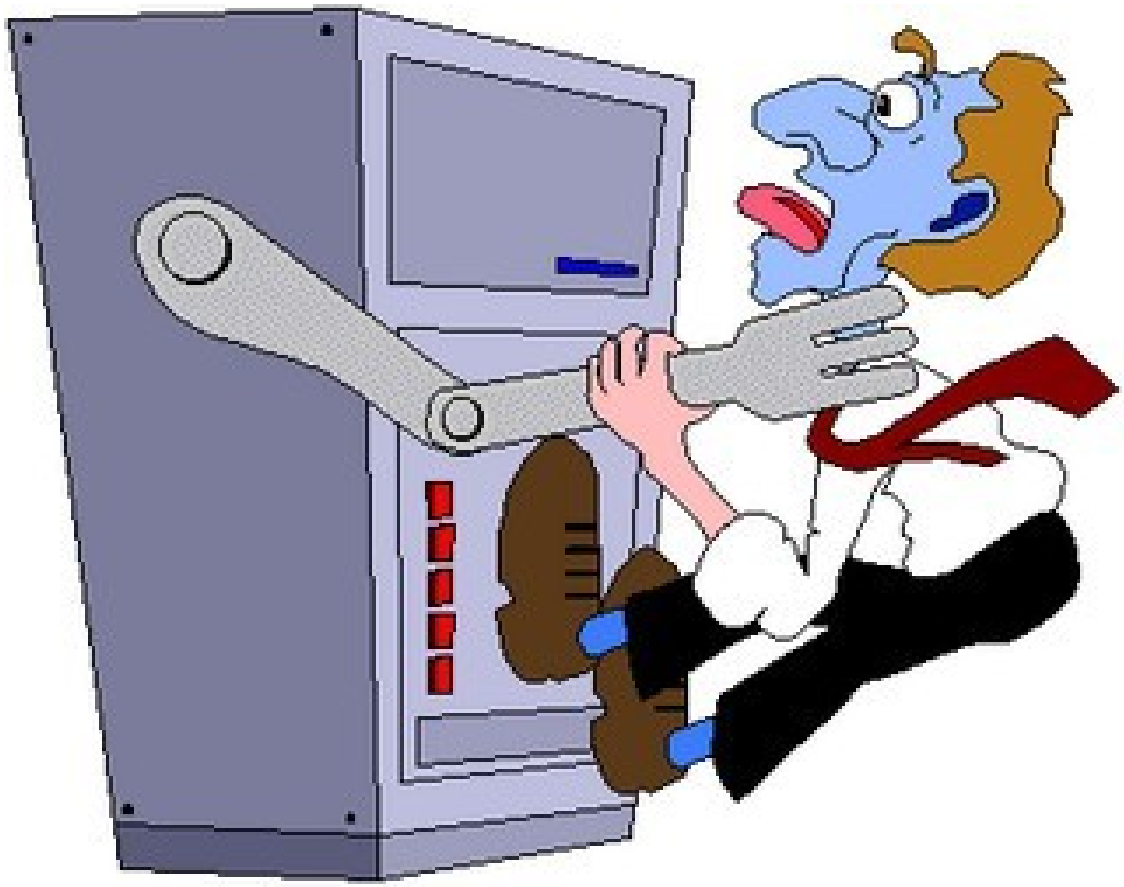
Automatic Archaeology?

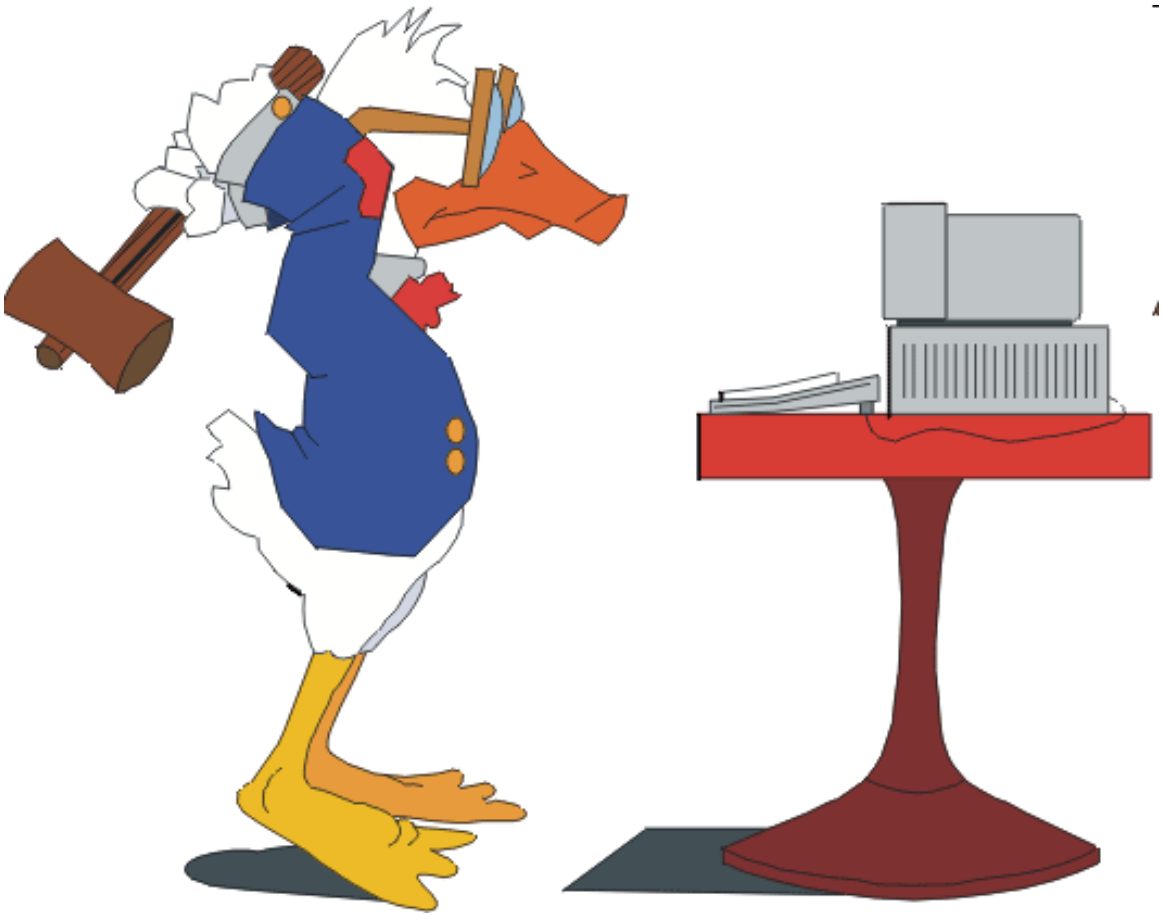
I THINK, THEREFORE
I UNDERSTAND
HUMANS,
EVEN IF THEY ACT
AS ARCHAEOLOGISTS



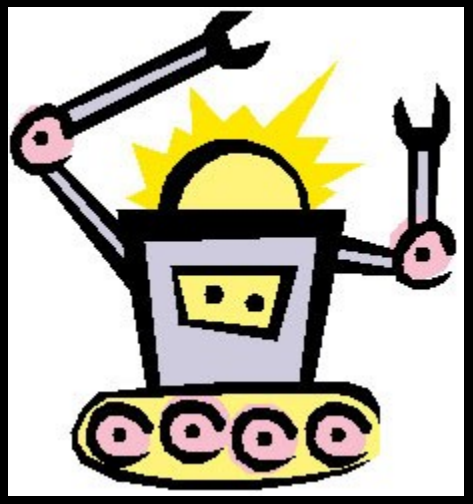

STAN HAD AN UNEASY FEELING ABOUT BUILDING
A ROBOT WORKFORCE TO IMPROVE PRODUCTIVITY


STUPID IDIOT !
Deacon





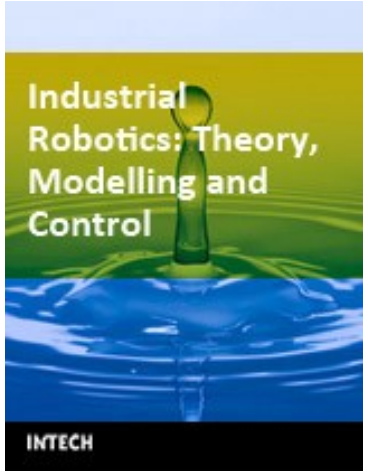
This is NOT a Science Fiction Tale

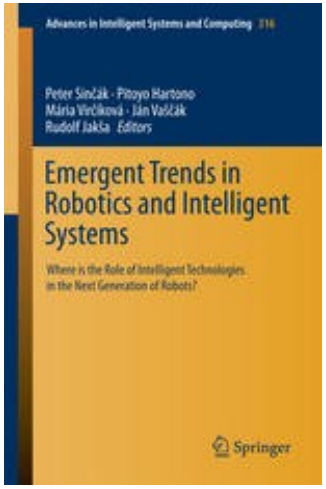


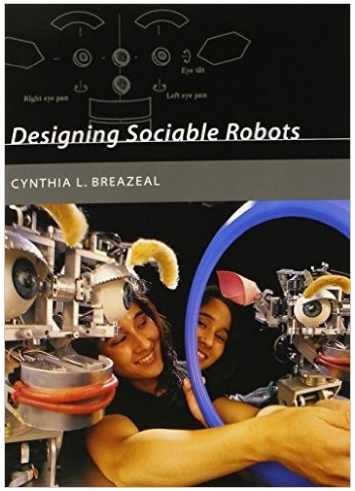
A robot called Archaeologist

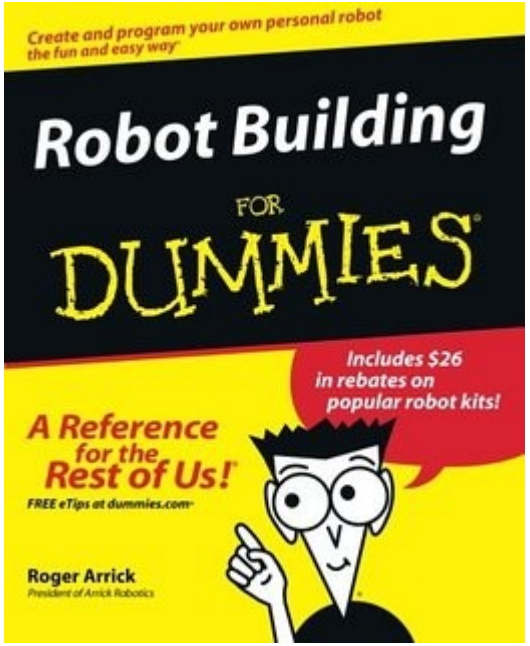

Make:
kits for the maker in all of us
Rovera 4W
Arduino Robot Kit
Make an Arduino-Controlled Robot
BOOK INCLUDED!
BUILD IN A WEEKEND!
A GREAT INTRODUCTION TO ROBOTICS AND ARDUINO
FOR BEGINNERS AND INTERMEDIATE BUILDERS
oreil.ly/ardbot
Make:
MAKER MADE


NEW
Robot Building
for Beginners
David Cook
SECOND EDITION

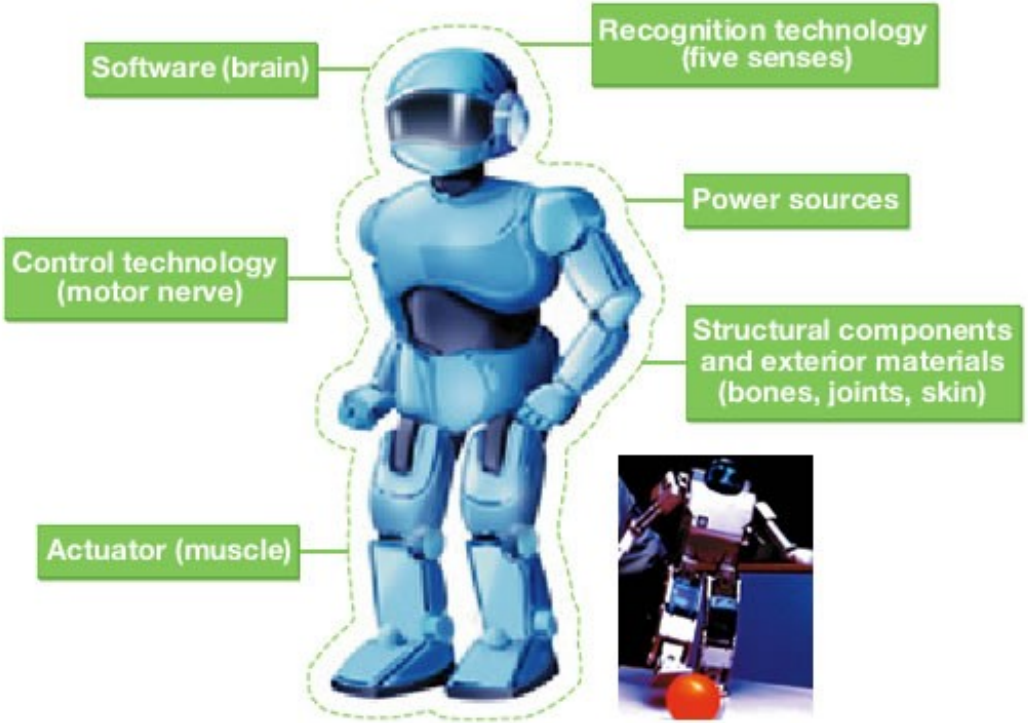

Industrial Robotics: Theory, Modelling and Control
INTECH

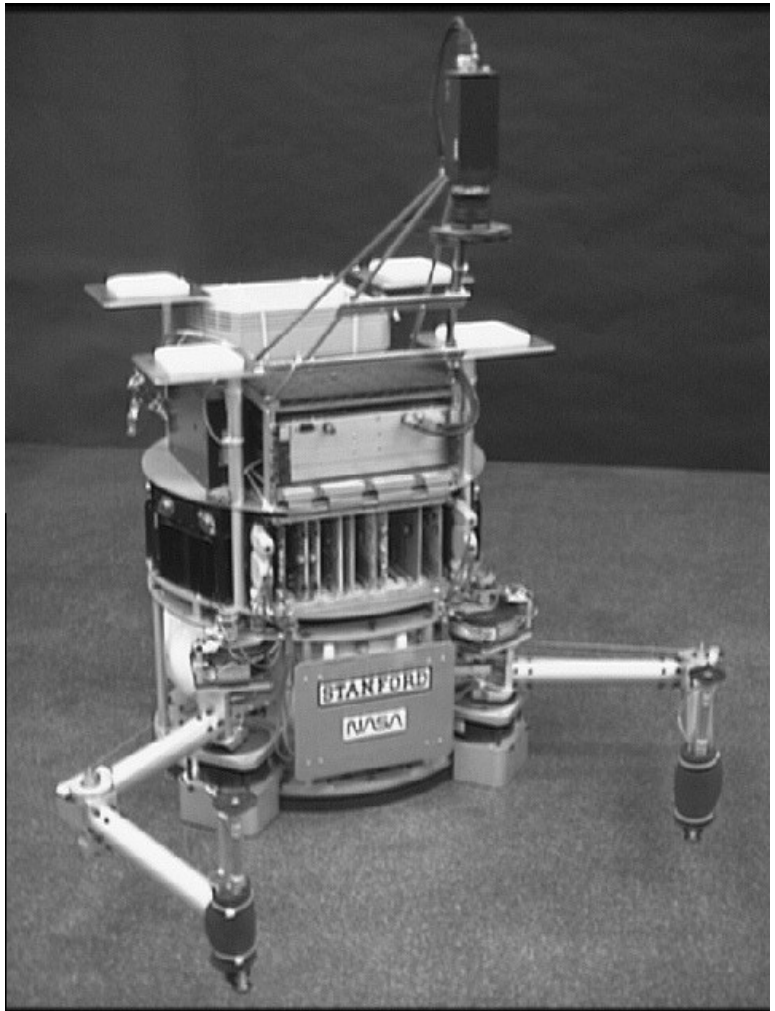

Advances in Intelligent Systems and Computing 316
Peter Šinčák · Pitoyo Hartono
Mária Virčíková · Ján Vaščák
Rudolf Jakša Editors
Emergent Trends in Robotics and Intelligent Systems
Where is the Role of Intelligent Technologies in the Next Generation of Robots?
Springer


Designing Sociable Robots
CYNTHIA L. BREAZEAL

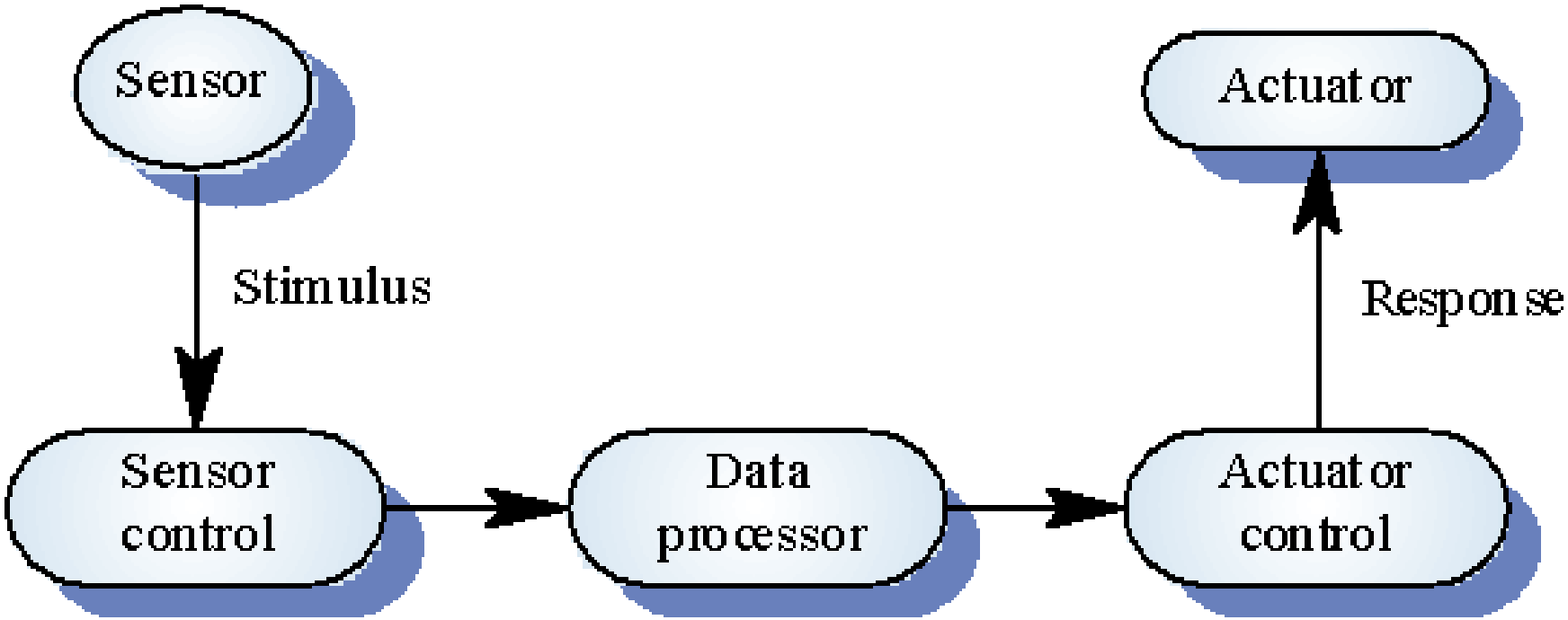

Create and program your own personal robot the fun and easy way
Robot Building
FOR
DUMMIES
Includes $26 in rebates on popular robot kits!
A Reference for the Rest of Us!
FREE eTips at dummies.com
Roger Arrick
President of Arrick Robotics

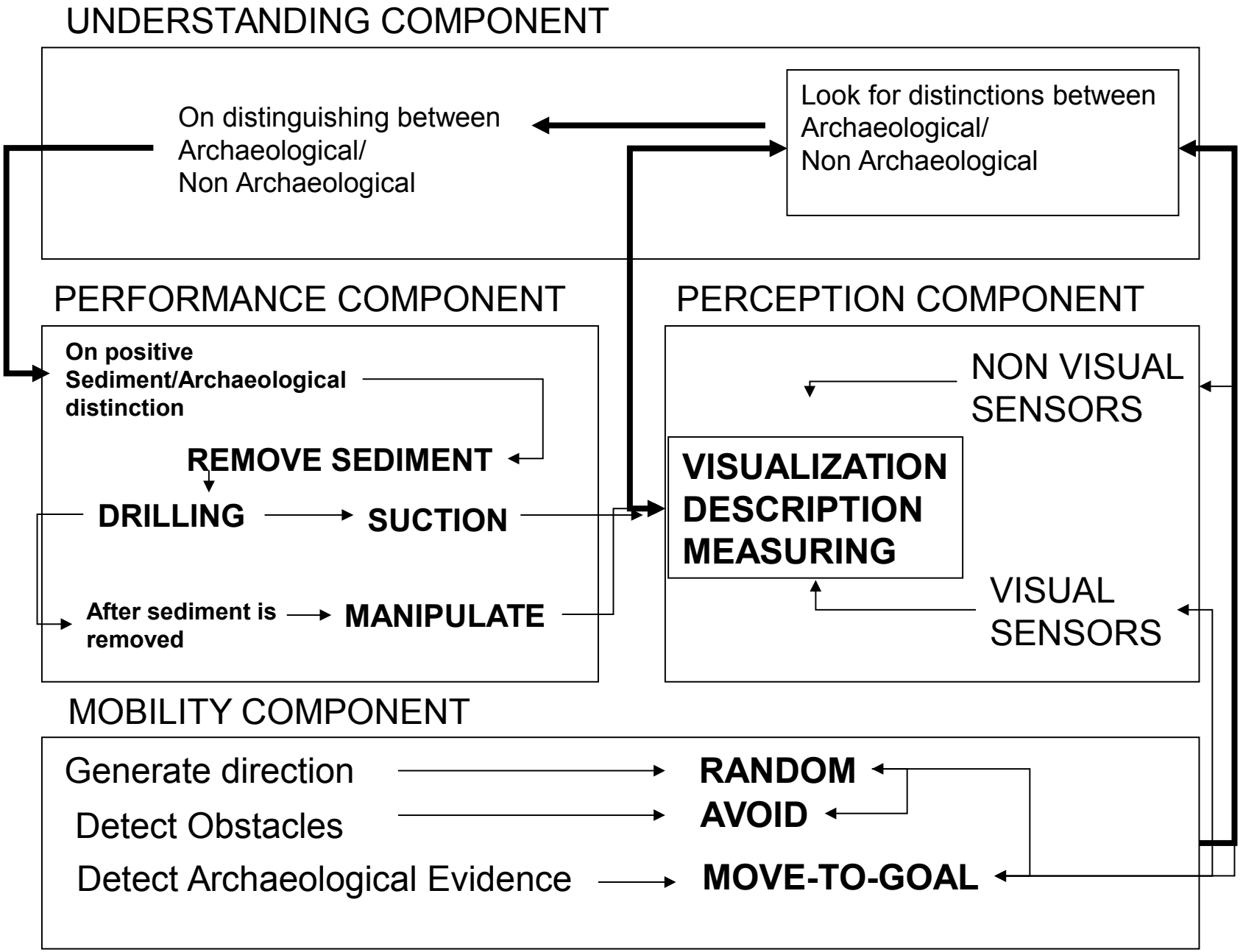
Components that constitute next-generation robotics

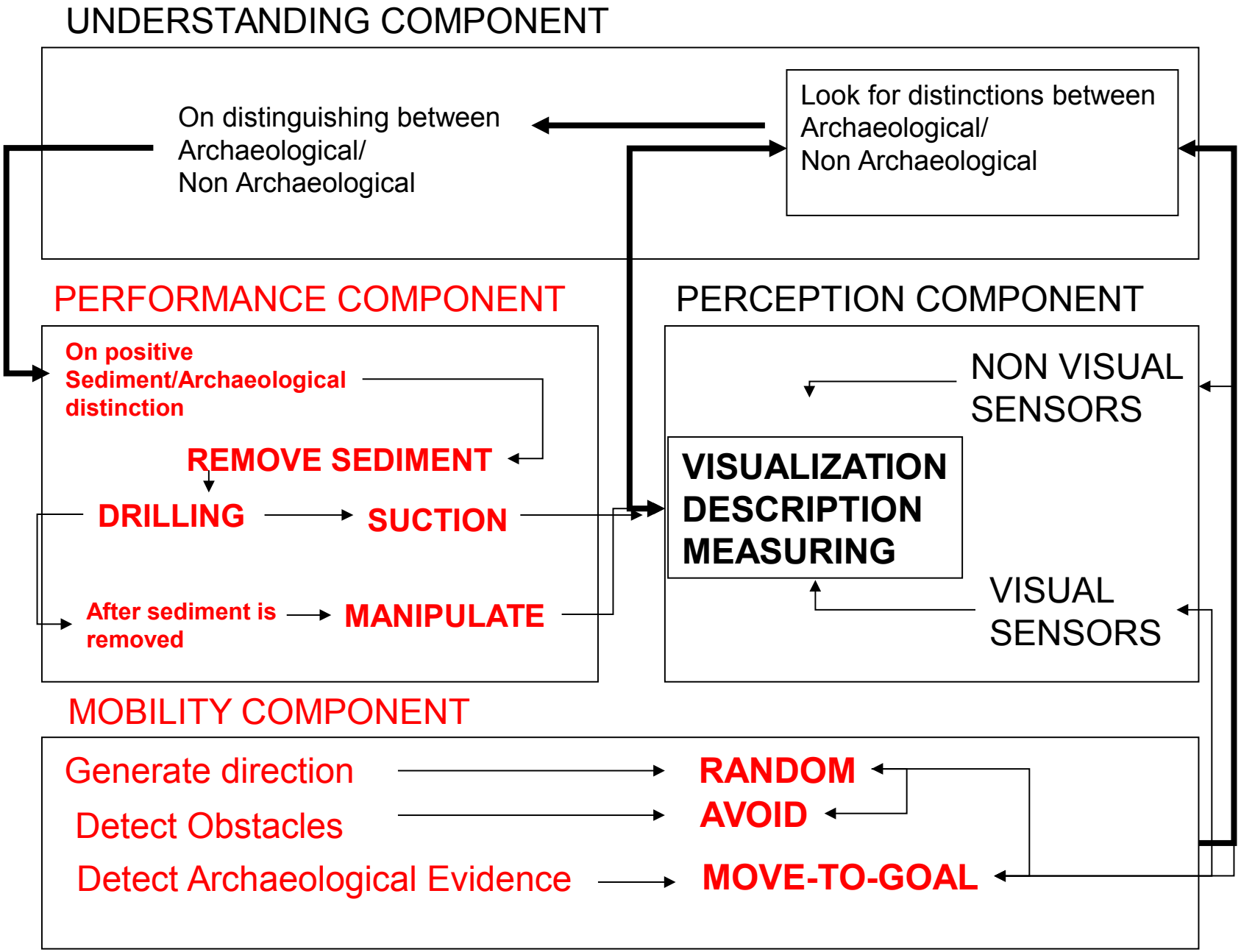


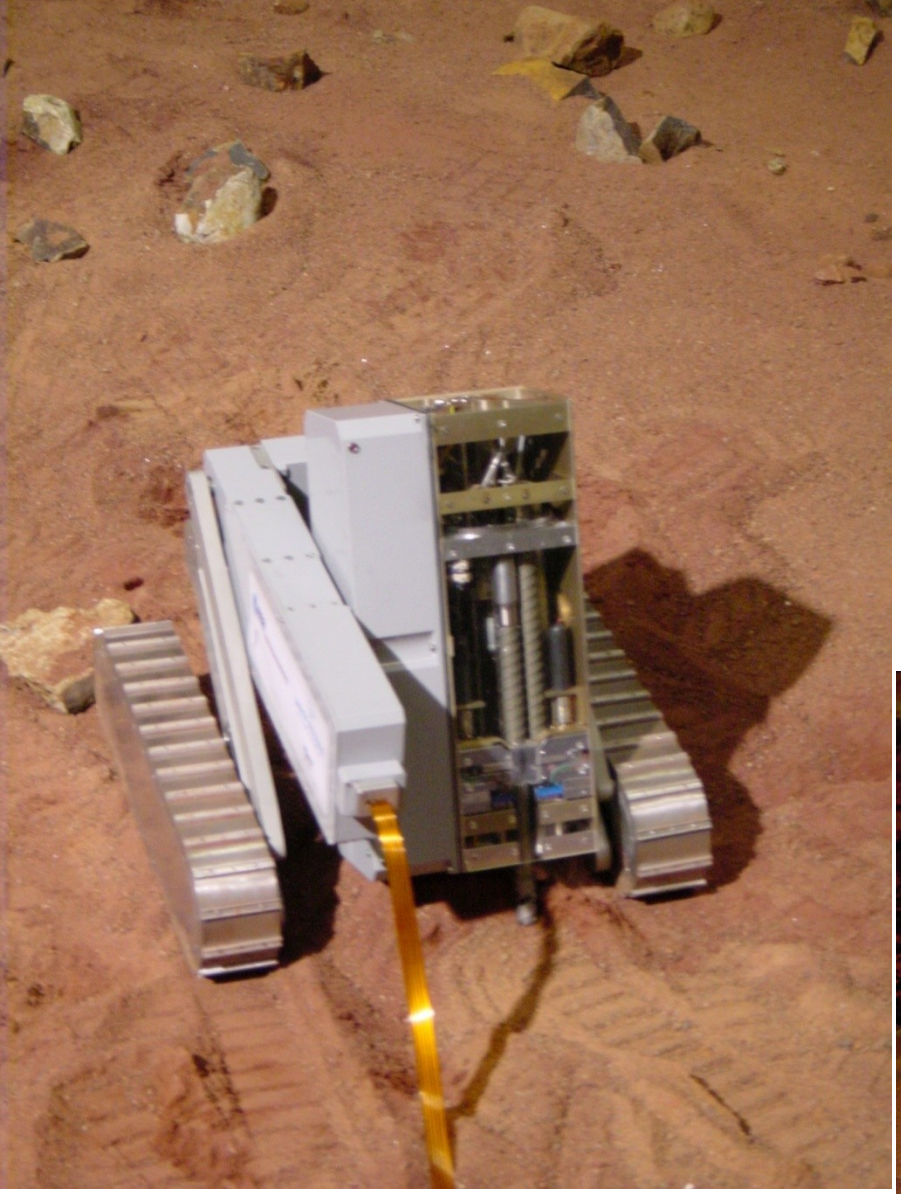


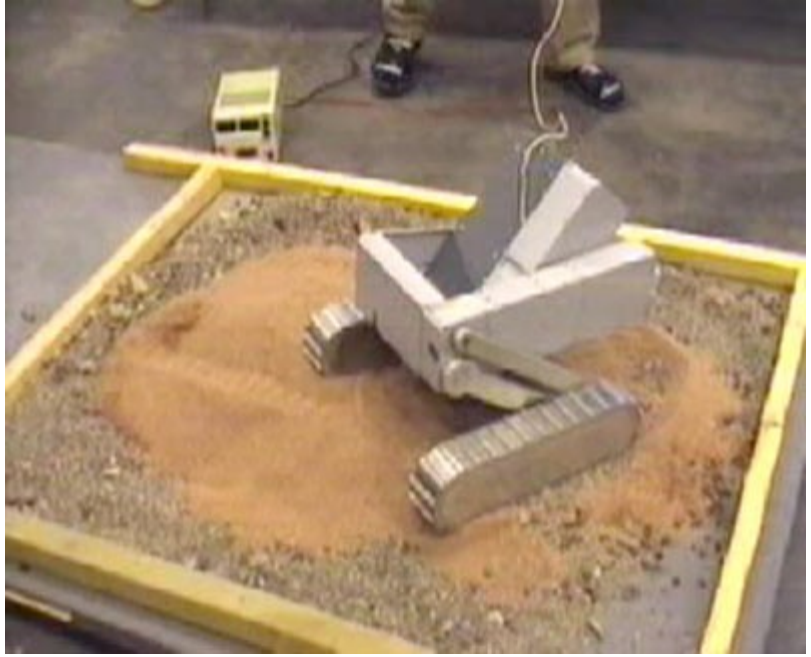
Sensor/actuator processes




UNDERSTANDING COMPONENT
On distinguishing between Archaeological/ Non Archaeological
Look for distinctions between Archaeological/ Non Archaeological
PERFORMANCE COMPONENT
On positive Sediment/Archaeological distinction
REMOVE SEDIMENT
DRILLING
SUCTION
After sediment is removed
MANIPULATE
PERCEPTION COMPONENT
NON VISUAL SENSORS
VISUALIZATION
DESCRIPTION
MEASURING
VISUAL SENSORS
MOBILITY COMPONENT
Generate direction
Detect Obstacles
Detect Archaeological Evidence
RANDOM
AVOID
MOVE-TO-GOAL


UNDERSTANDING COMPONENT
On distinguishing between Archaeological/ Non Archaeological
Look for distinctions between Archaeological/ Non Archaeological
PERFORMANCE COMPONENT
PERCEPTION COMPONENT
On positive Sediment/Archaeological distinction
REMOVE SEDIMENT
DRILLING
SUCTION
After sediment is removed
MANIPULATE
NON VISUAL SENSORS
VISUALIZATION
DESCRIPTION
MEASURING
VISUAL SENSORS
MOBILITY COMPONENT
Generate direction
Detect Obstacles
Detect Archaeological Evidence
RANDOM
AVOID
MOVE-TO-GOAL

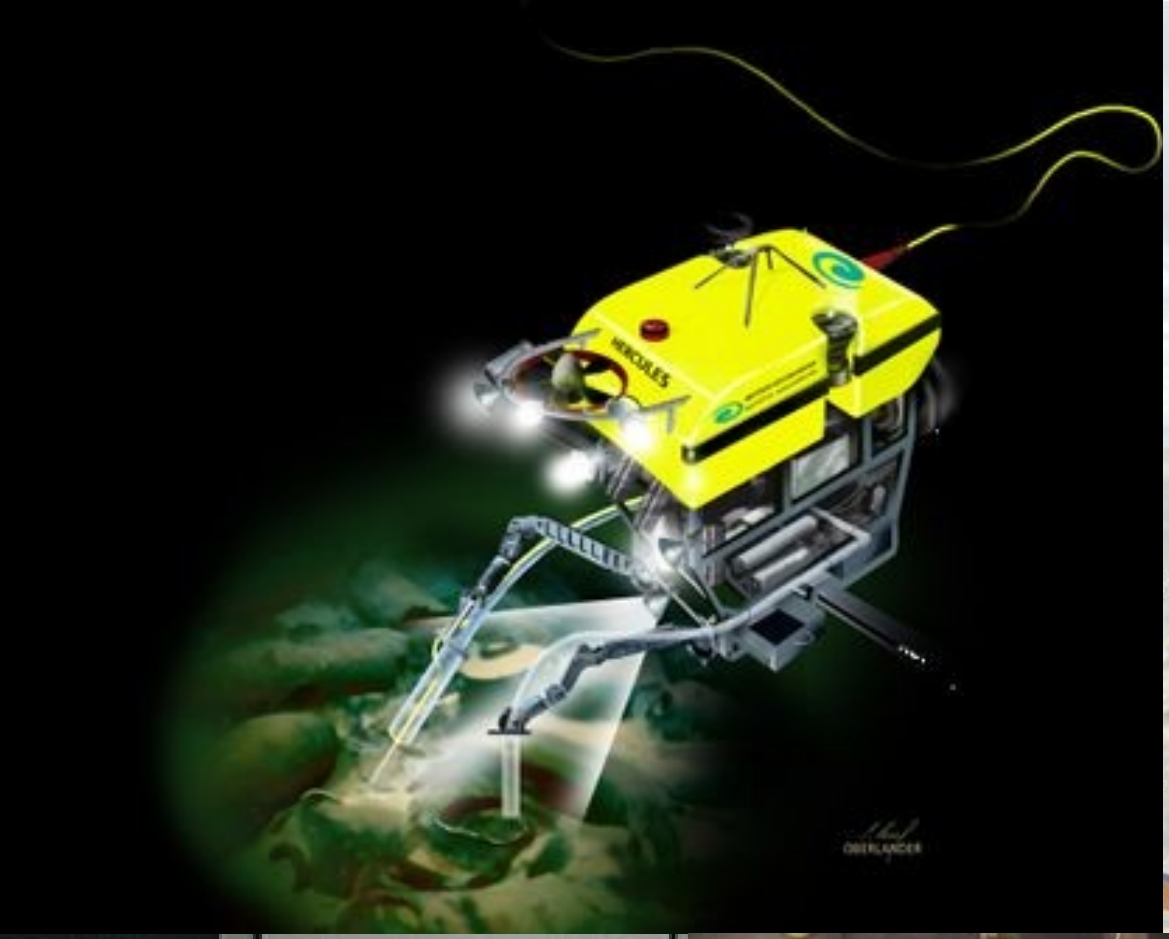


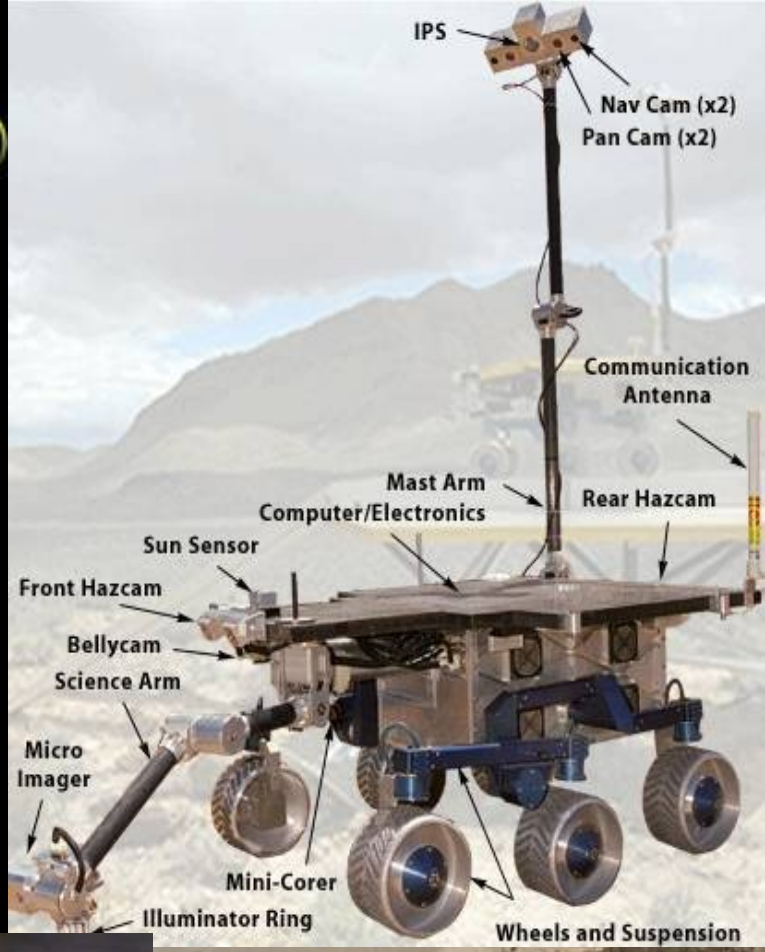


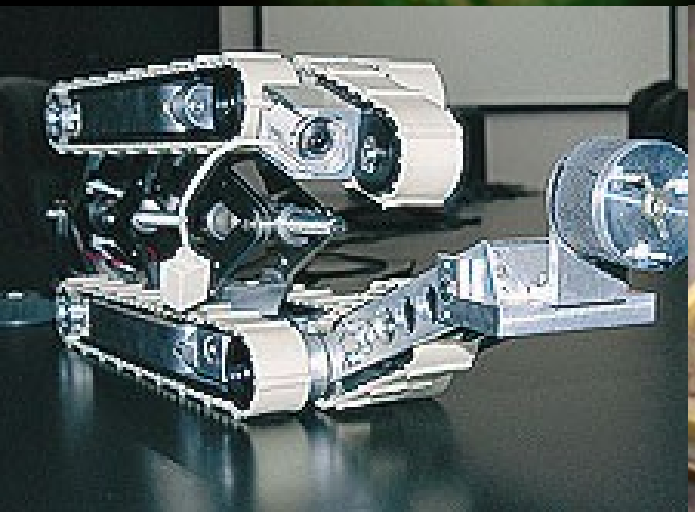
EUROPEAN SPACE AGENCY

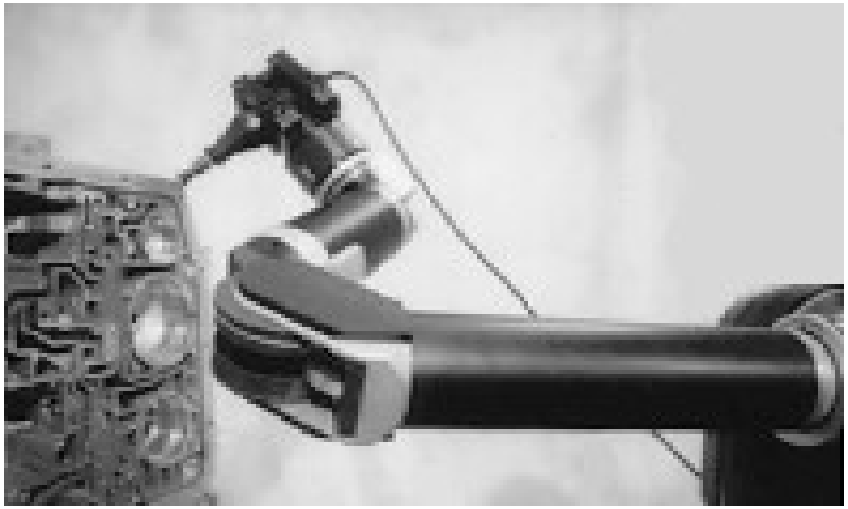
Micro Robots for Scientific Applications 2

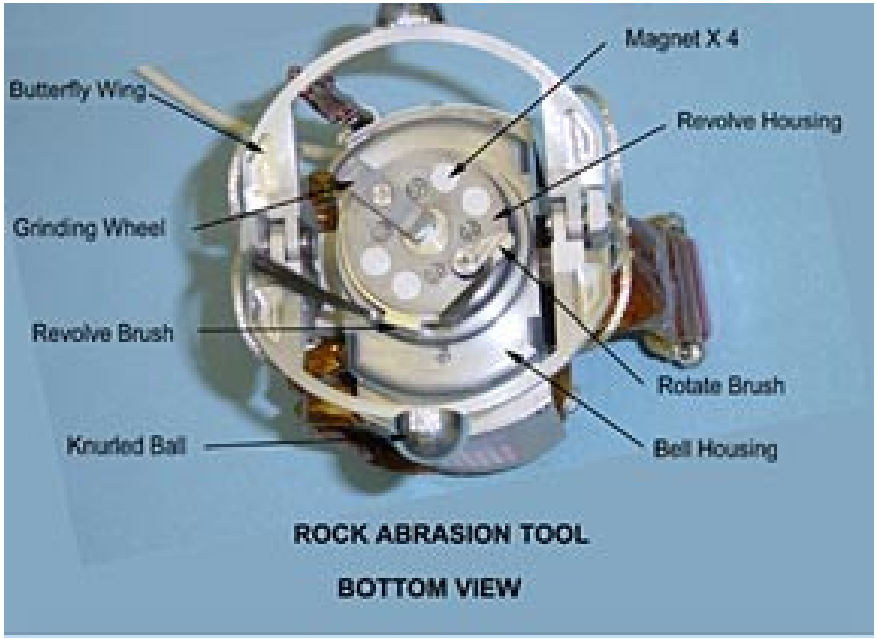
http://antti.la/mrosa2/

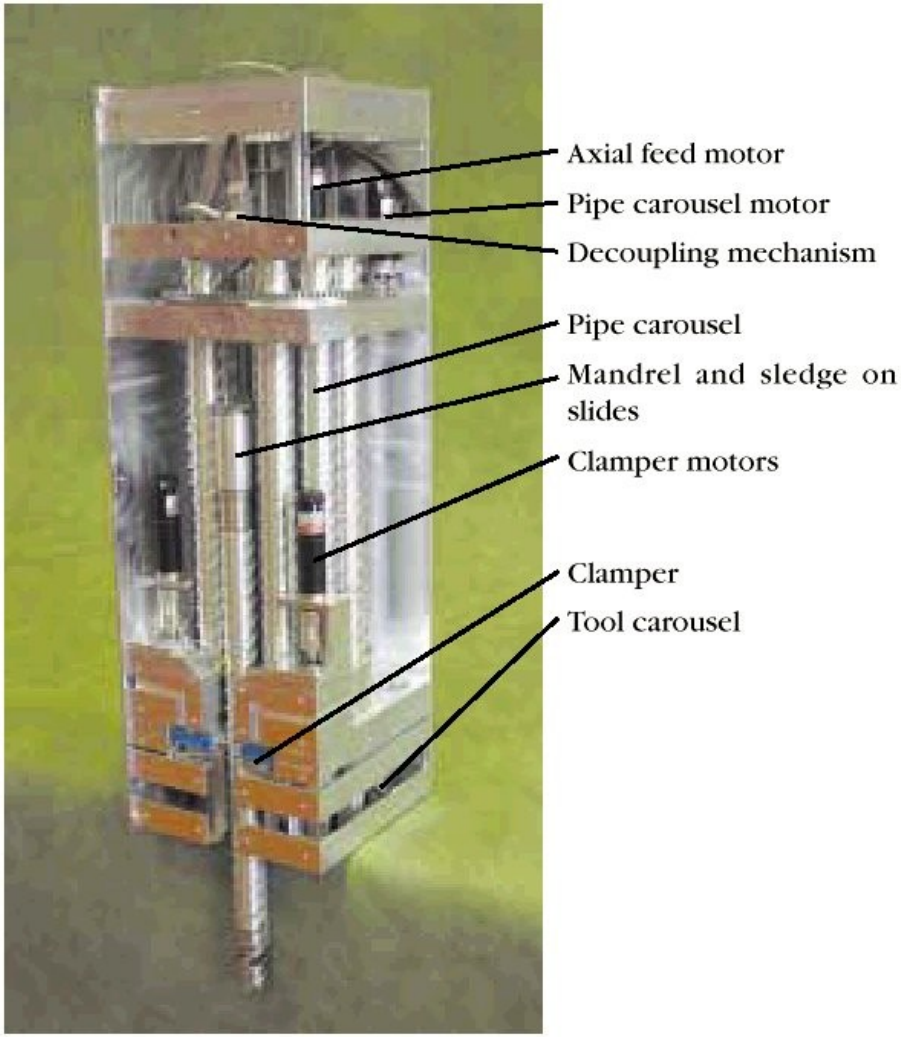

HERCULES

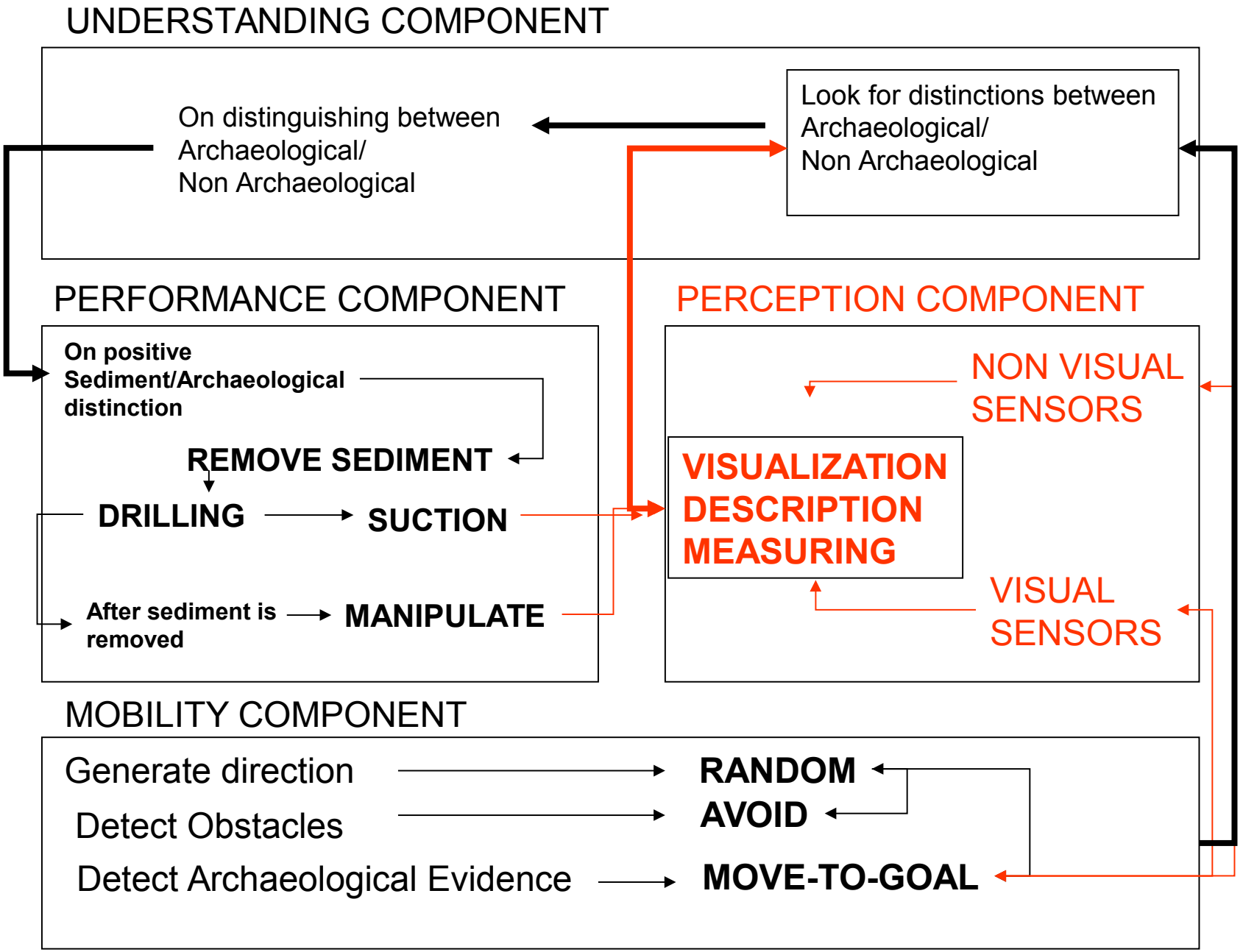

IPS
Nav Cam (x2)
Pan Cam (x2)
Communication Antenna
Mast Arm
Computer/Electronics
Rear Hazcam
Sun Sensor
Front Hazcam
Bellycam
Science Arm
Micro Imager
Mini-Corer
Illuminator Ring
Wheels and Suspension

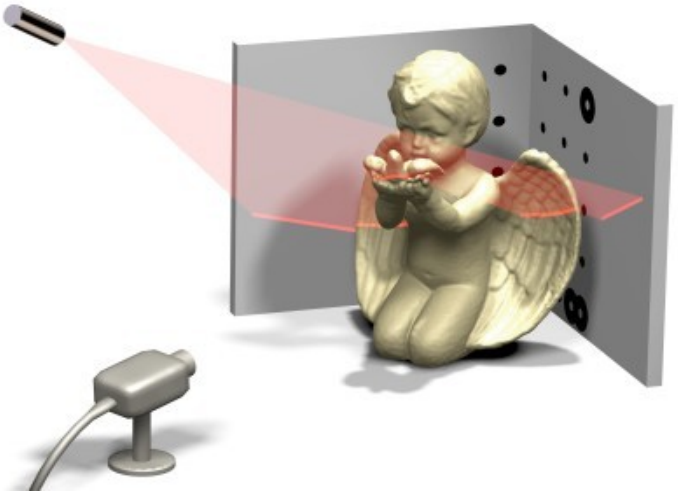





Magnet X 4
Butterfly Wing
Revolve Housing
Grinding Wheel
Revolve Brush
Rotate Brush
Knurled Ball
Bell Housing
ROCK ABRASION TOOL
BOTTOM VIEW


Axial feed motor
Pipe carousel motor
Decoupling mechanism
Pipe carousel
Mandrel and sledge on slides
Clamper motors
Clamper
Tool carousel


UNDERSTANDING COMPONENT
On distinguishing between Archaeological/ Non Archaeological
Look for distinctions between Archaeological/ Non Archaeological
PERFORMANCE COMPONENT
On positive Sediment/Archaeological distinction
REMOVE SEDIMENT
DRILLING
SUCTION
After sediment is removed
MANIPULATE
PERCEPTION COMPONENT
NON VISUAL SENSORS
VISUALIZATION
DESCRIPTION
MEASURING
VISUAL SENSORS
MOBILITY COMPONENT
Generate direction
Detect Obstacles
Detect Archaeological Evidence
RANDOM
AVOID
MOVE-TO-GOAL



3D Scanning

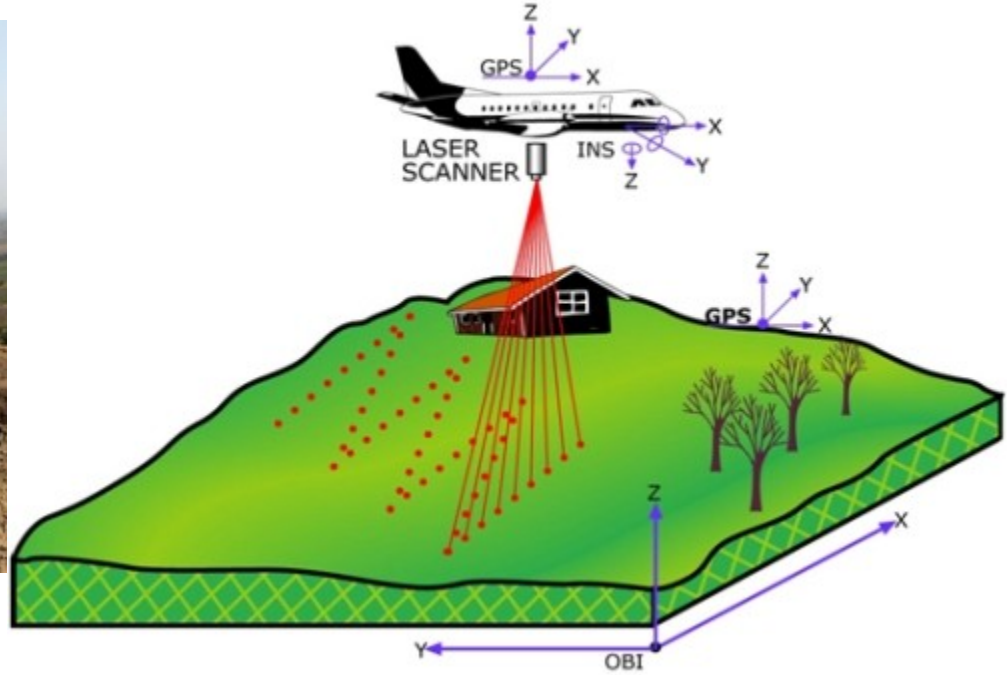
3D Scanning

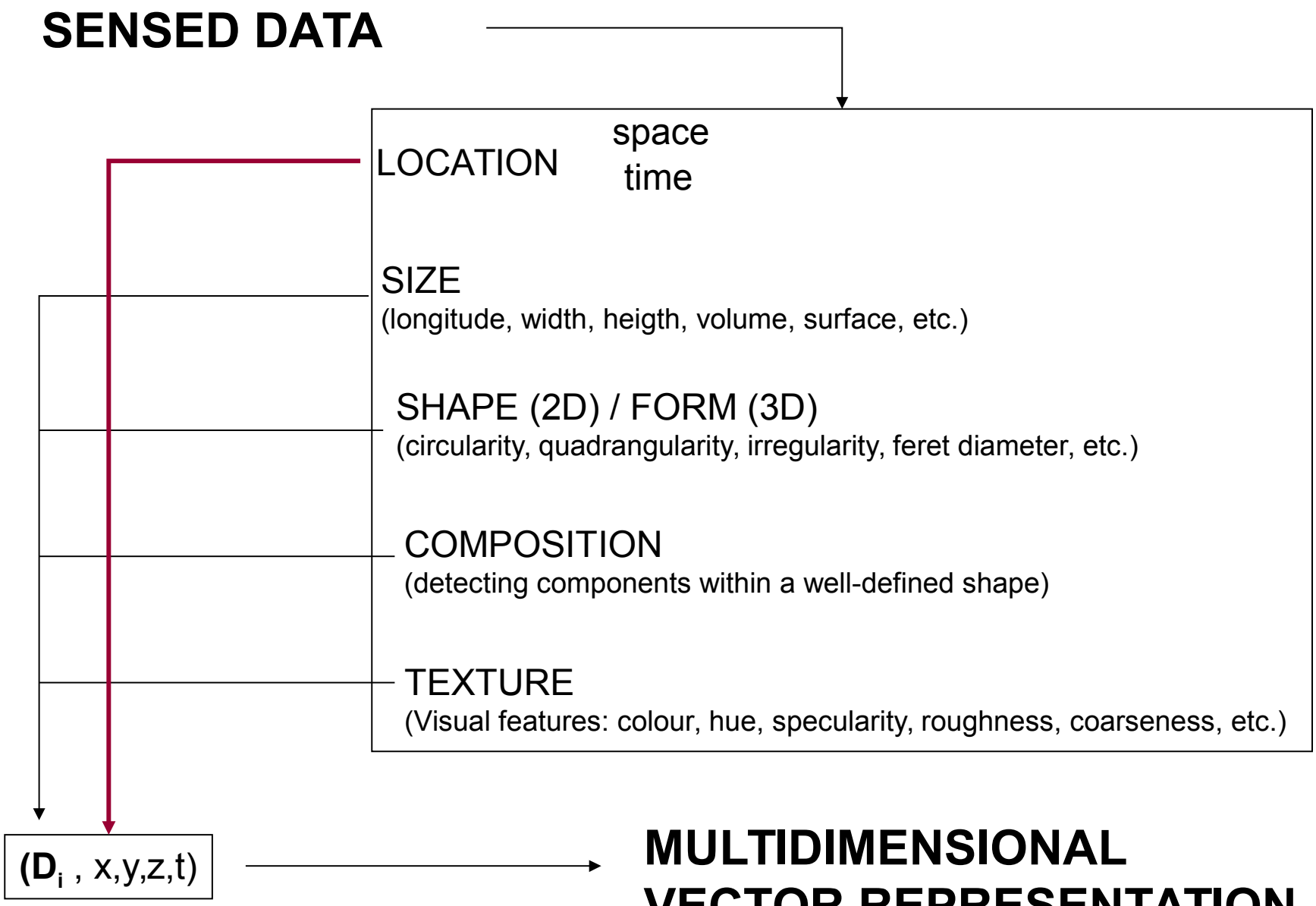
3D Scanning

BREUKMAN OTO
Institució Milà i Fontanals
(CSIC)

Minolta Vivid
UAB-CVC

LASER SCANNING




SENSED DATA
LOCATION
space
time
SIZE
(longitude, width, heigth, volume, surface, etc.)
SHAPE (2D) / FORM (3D)
(circularity, quadrangularity, irregularity, feret diameter, etc.)
COMPOSITION
(detecting components within a well-defined shape)
TEXTURE
(Visual features: colour, hue, specularity, roughness, coarseness, etc.)
(D_i , x,y,z,t)
MULTIDIMENSIONAL
VECTOR REPRESENTATION

Real Data, Virtual Excavation

Barceló, J.A.; 2009, Mameli, L.; Maximiano, A.; Vicente, O..
New Computational and Mathematical Methods for Archaeological Fieldwork at the Extreme South of the Populated World
.
Arctic Anthropology 46(1-2): 203-214.

Barceló, J.A.; Vicente, O., 2004,
Some Problems in Archaeological Excavation 3D Modeling. In *Enter the Past. The E-way into the Four Dimensions of Culture Heritage.* Oxford: ArcheoPress. (BAR International Series 1227) Pp. 400-405.

UNIVERSITAT AUTONOMA BARCELONA/INSTITUCIÓ MILÀ i FONTANALS (CSIC). SPAIN
CENTRO AUSTRAL INVESTIGACIONES CIENTIFICAS. ARGENTINA

Universitat Autònoma de Barcelona

Arqueología y Antropología

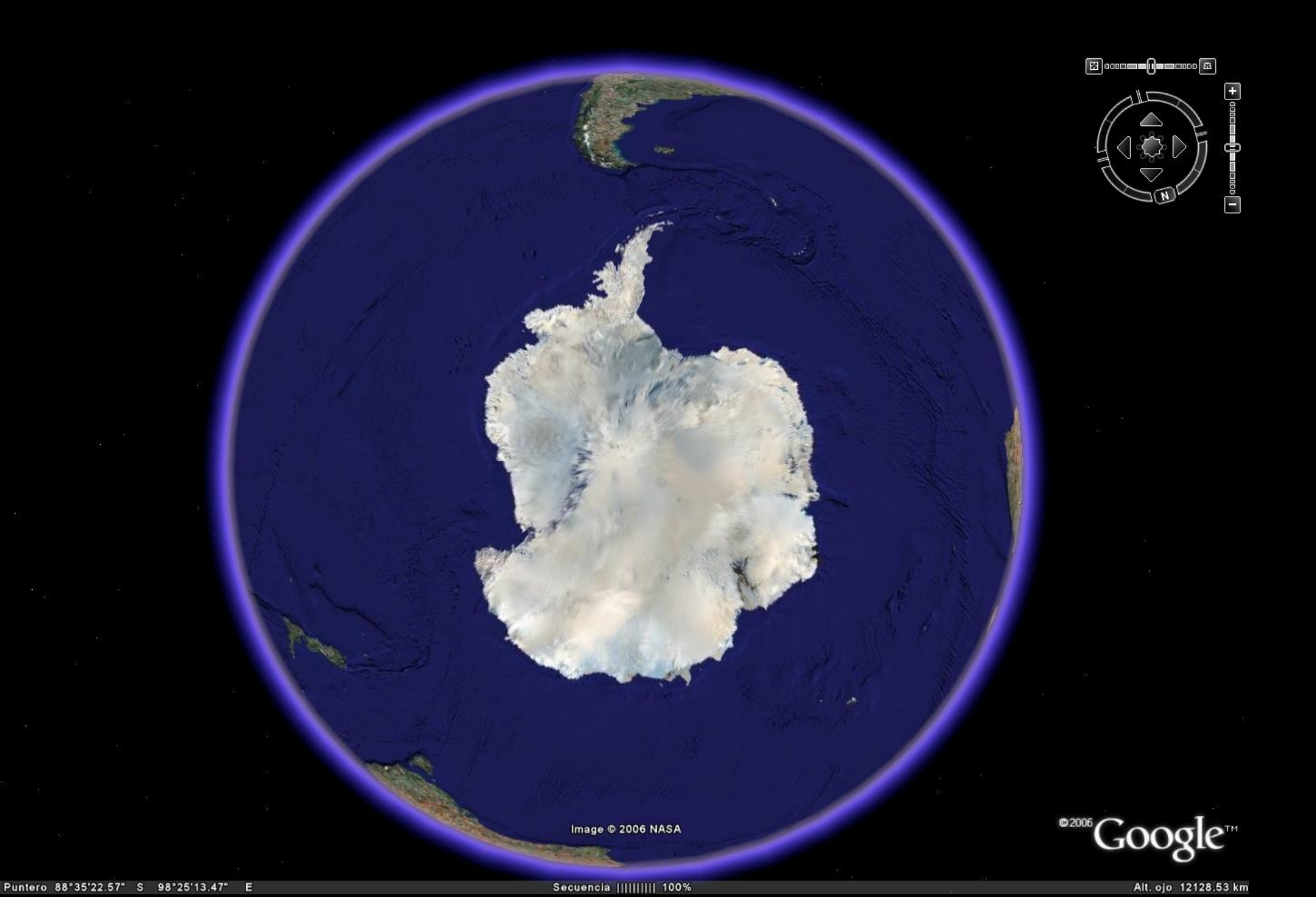


Image © 2006 NASA
©2006 Google™
Puntero 88°35'22.57" S 98°25'13.47" E
Secuencia 100%
Alt. ojo 12128.53 km

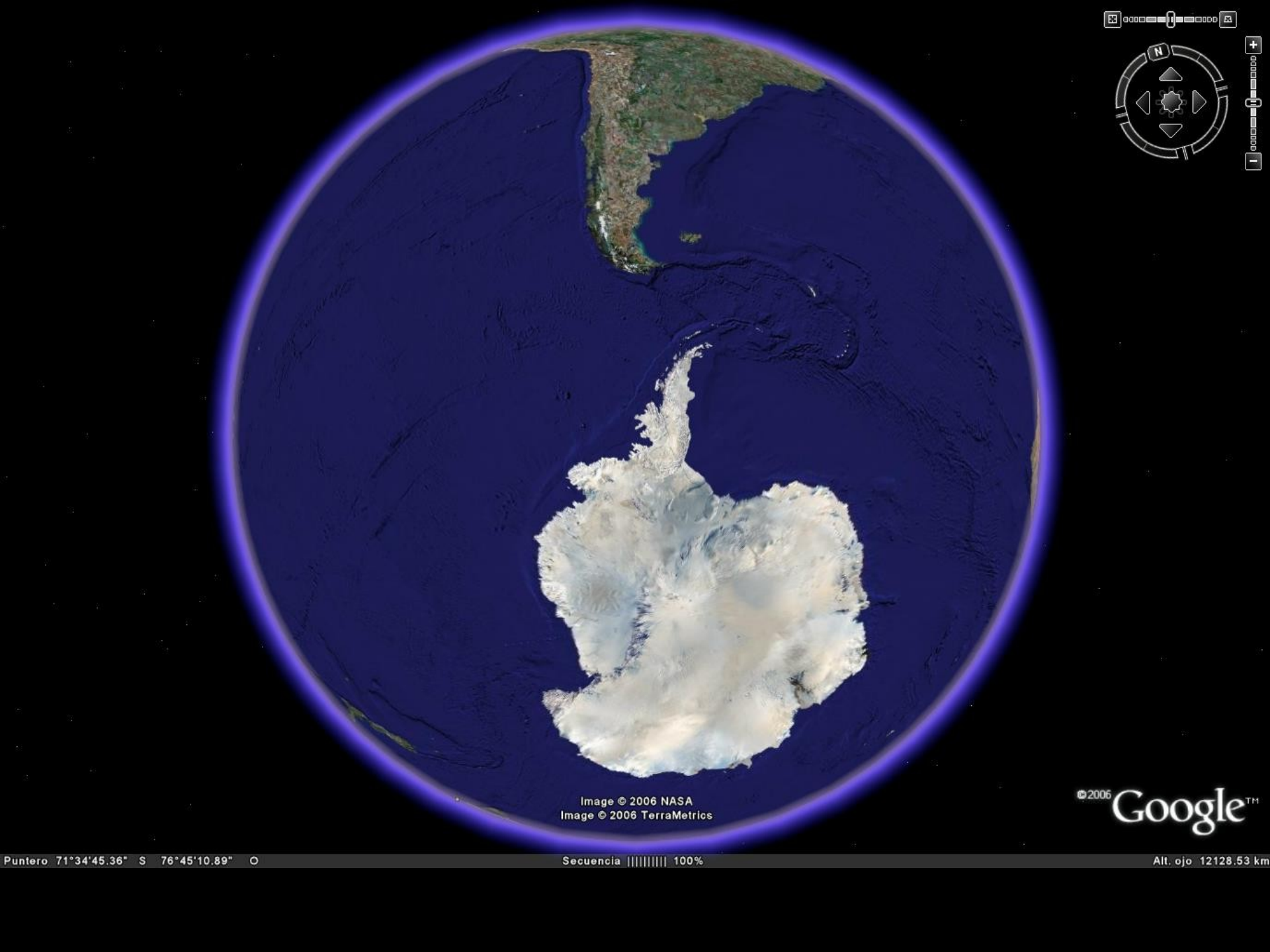
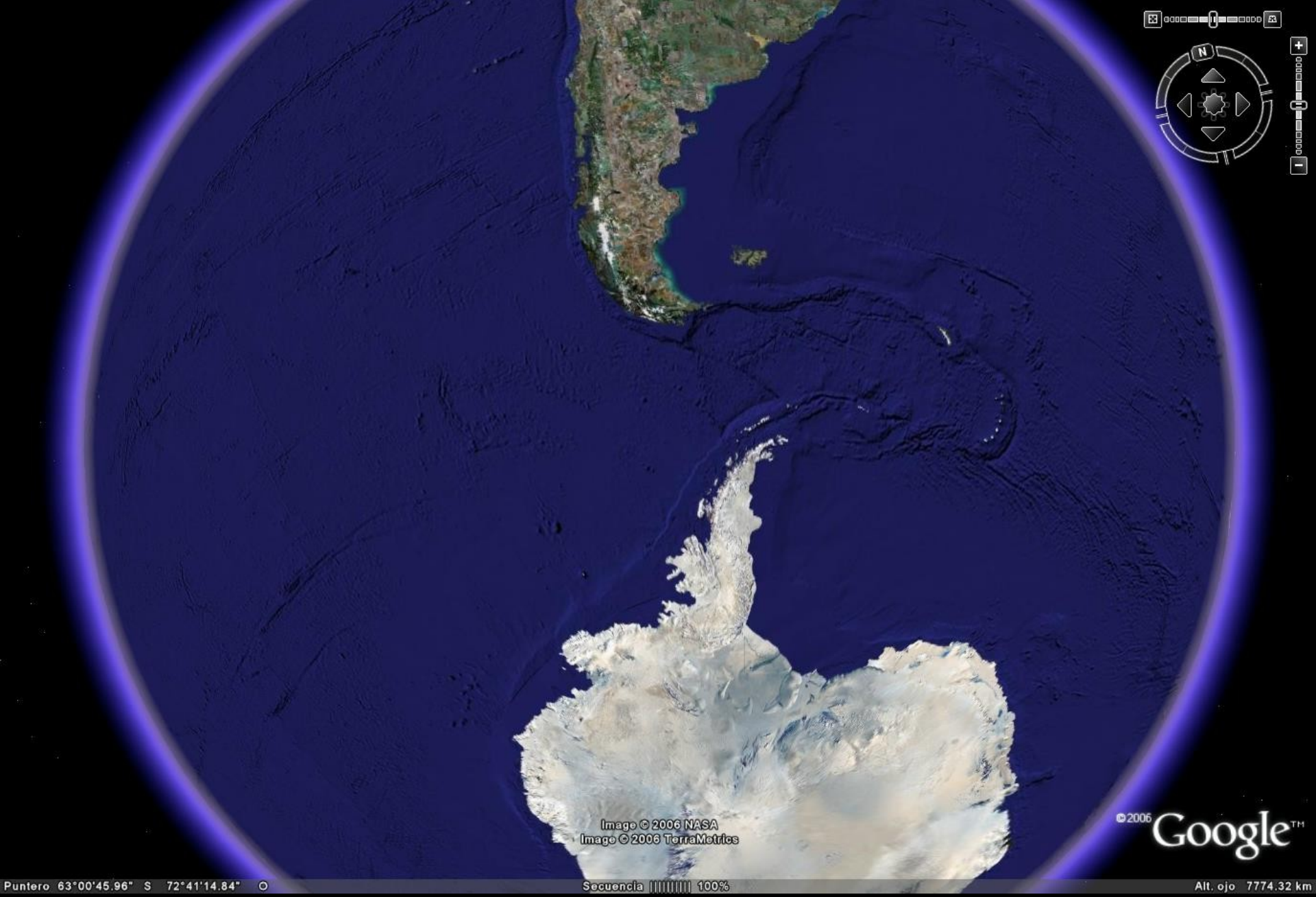


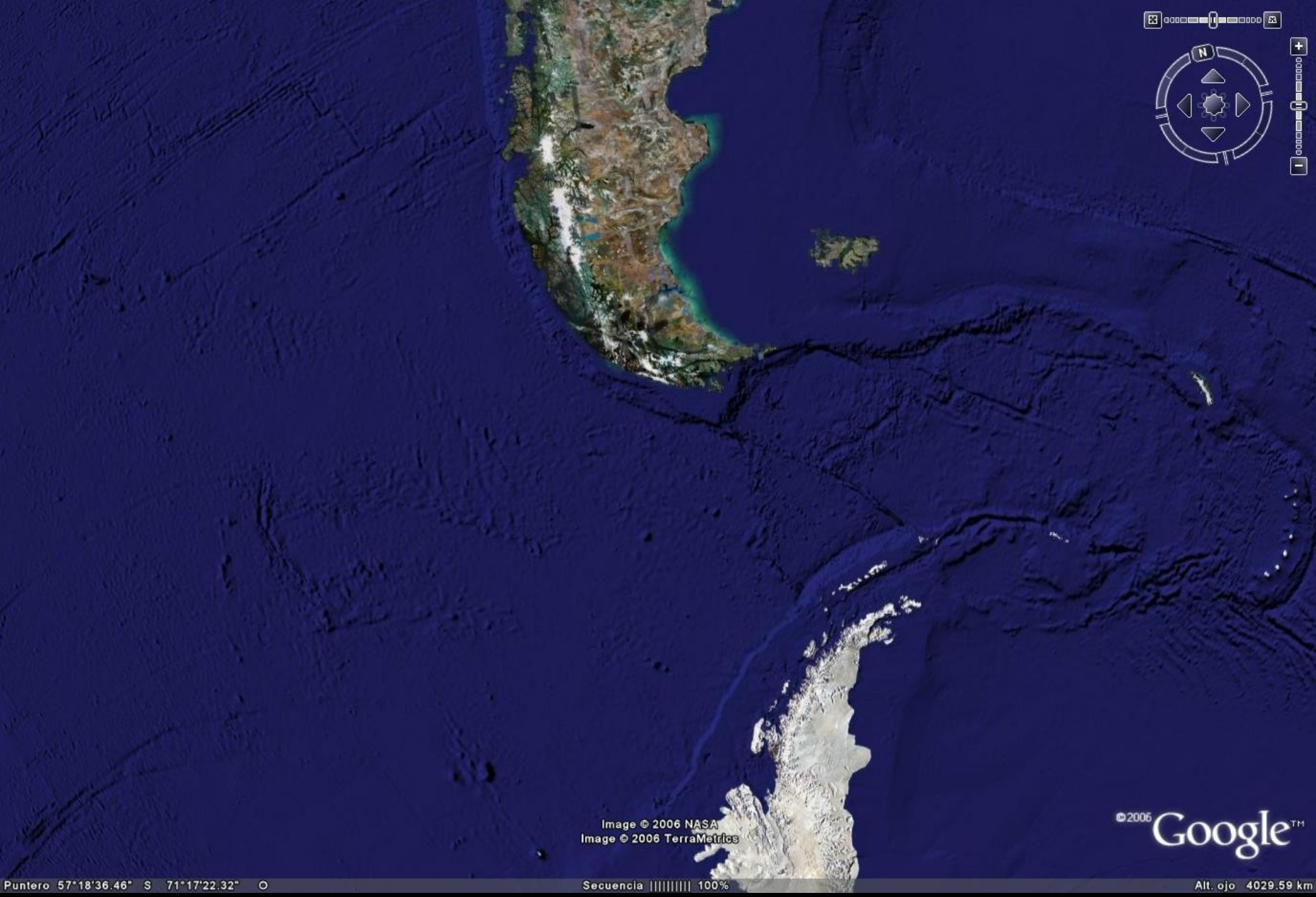
Image © 2006 NASA
Image © 2006 TerraMetrics
©2006 Google™
Puntero 71°34'45.36" S 76°45'10.89" O
Secuencia 100%
Alt. ojo 12128.53 km



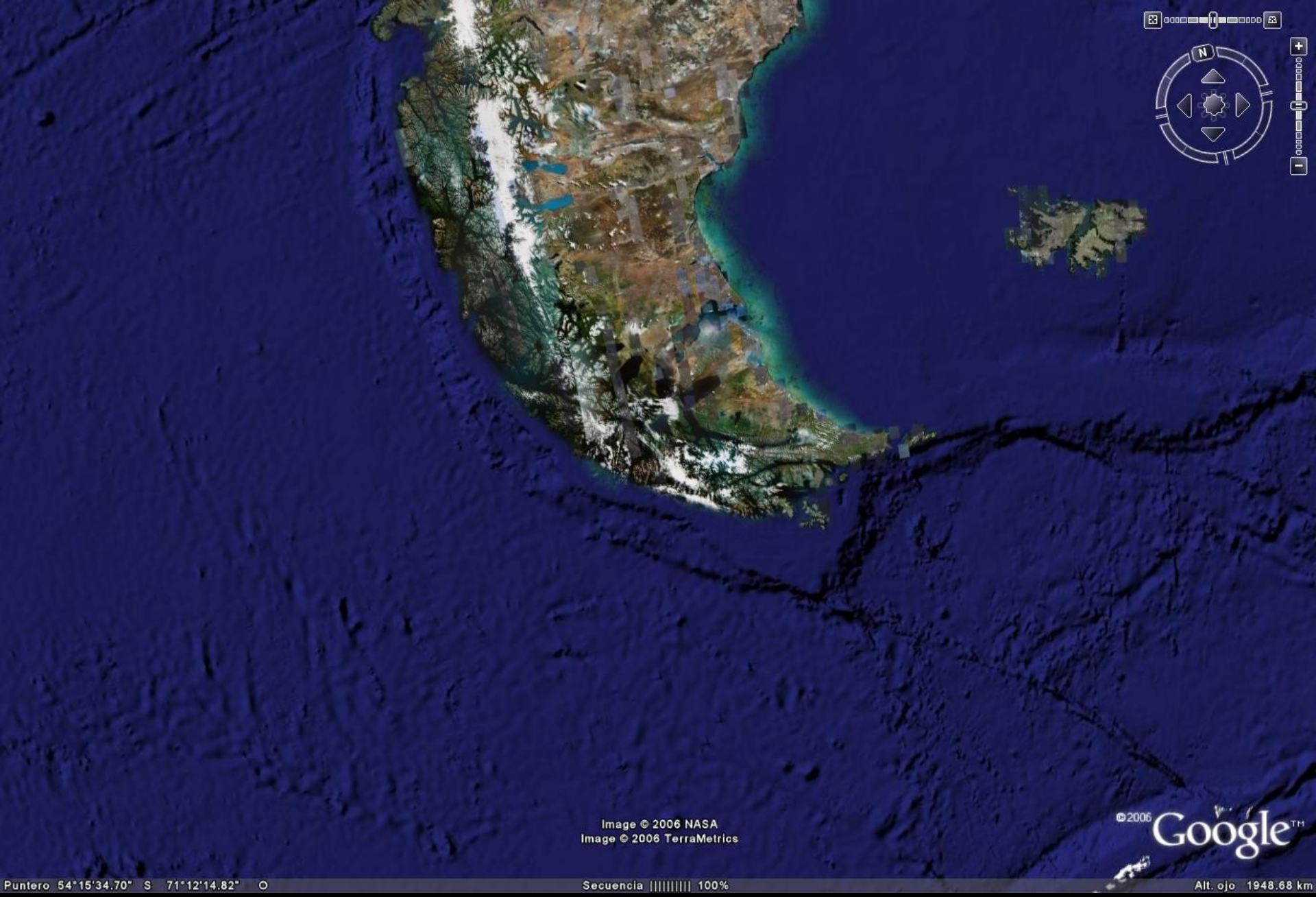
Puntero 63°00'45.96" S 72°41'14.84" O

Secuencia 100%

Alt. ojo 7774.32 km



Puntero 57°18'36.46" S 71°17'22.32" O Secuencia ||||||||| 100% Alt. ojo 4029.59 km

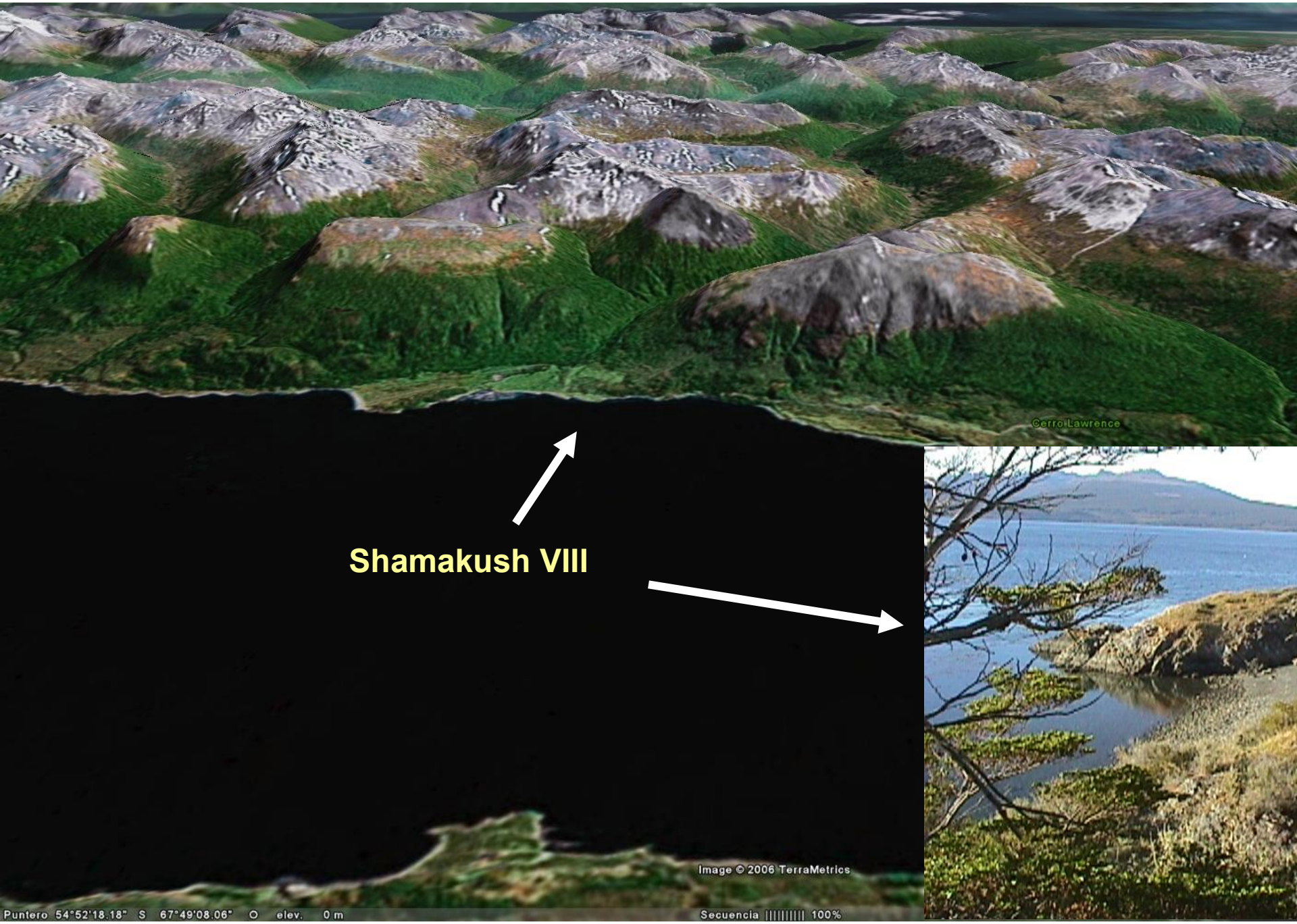

N
Image © 2006 NASA
Image © 2006 TerraMetrics
©2006 Google™
Puntero 54°15'34.70" S 71°12'14.82" O
Secuencia |||||||||| 100%
Alt. ojo 1948.68 km


N
Image © 2006 NASA
Image © 2006 TerraMetrics
©2006 Google™
Puntero 54°54'12.89" S 70°31'52.86" O elev. 65 m
Secuencia 1%
Alt. ojo 867.69 k

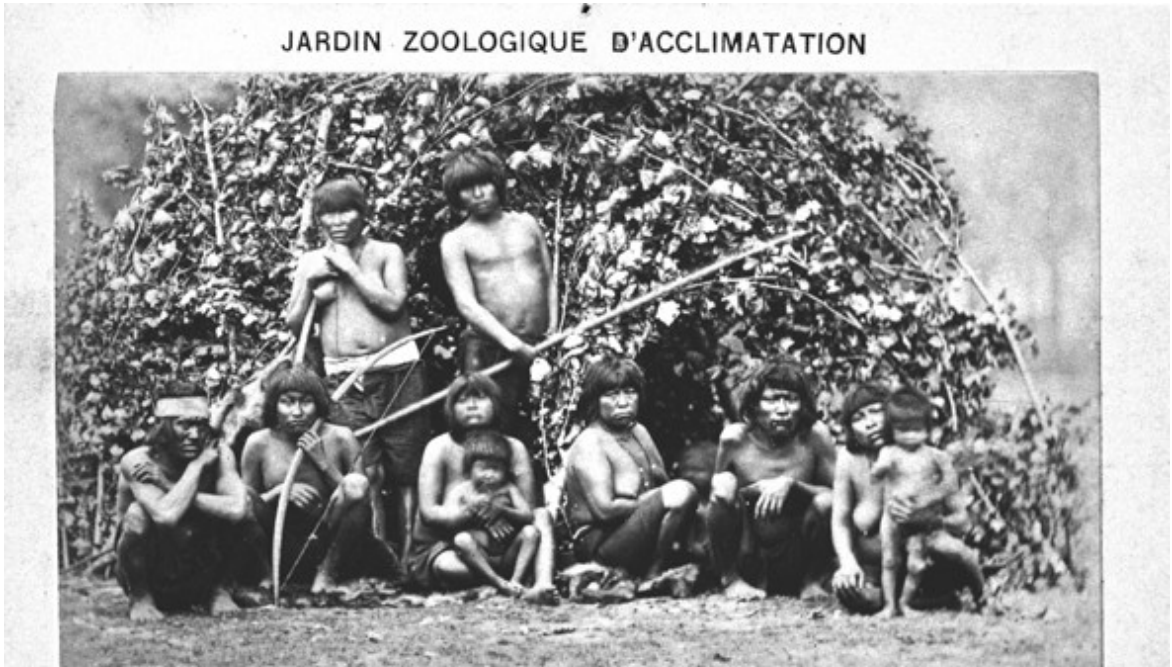

N
Image © 2006 NASA
Image © 2006 TerraMetrics
©2006 Google
Puntero 55°16'29.38" S 68°42'02.95" O elev. 276 m
Secuencia 100%
Alt. ojo 459.02 k


N
Image © 2006 NASA
Image © 2006 TerraMetrics
©2006 Google™
Puntero 55°07'41.54" S 67°37'24.91" O elev. 238 m
Secuencia 100%
Alt. ojo 285.01 k


N
Image © 2006 TerraMetrics
©2006 Google
Puntero 55°01'36.97" S 67°41'55.11" O elev. 584 m
Secuencia |||||||||| 100%
Alt. ojo 142.02 k


Cerro Lawrence
Shamakush VIII
Image © 2006 TerraMetrics
Puntero 54°52'18.18" S 67°49'08.06" O elev. 0 m
Secuencia 100%

Yamana people lived in small huts, fires for cooking and warmth were placed inside the huts and the refuse, primarily the quickly accumulating shells, was tossed outside the huts.



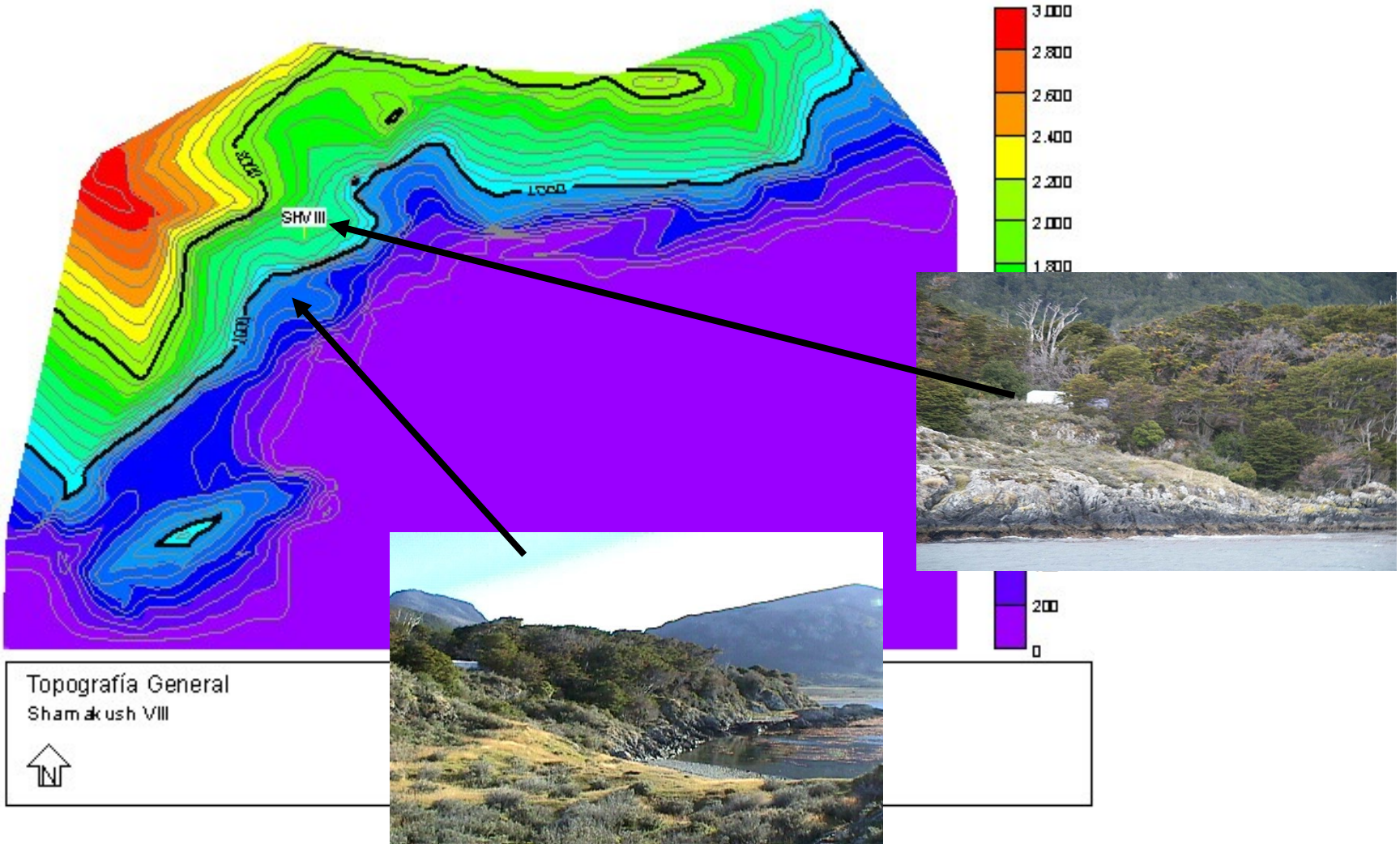
Archaeology and Ethnoarchaeology at the *bottom* of the world

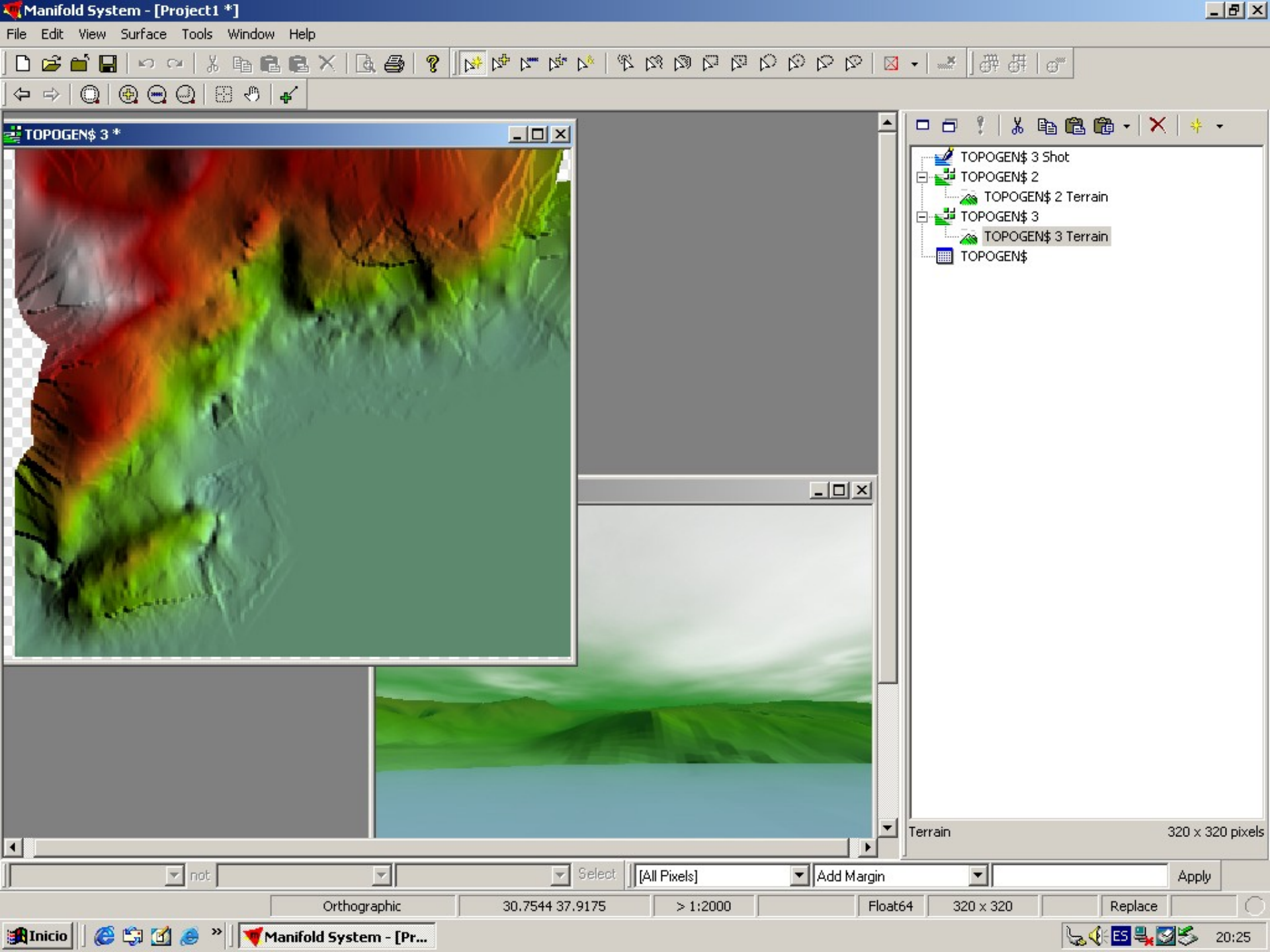
Archaeological sites on the coast of Tierra del Fuego have been described as shell-middens.

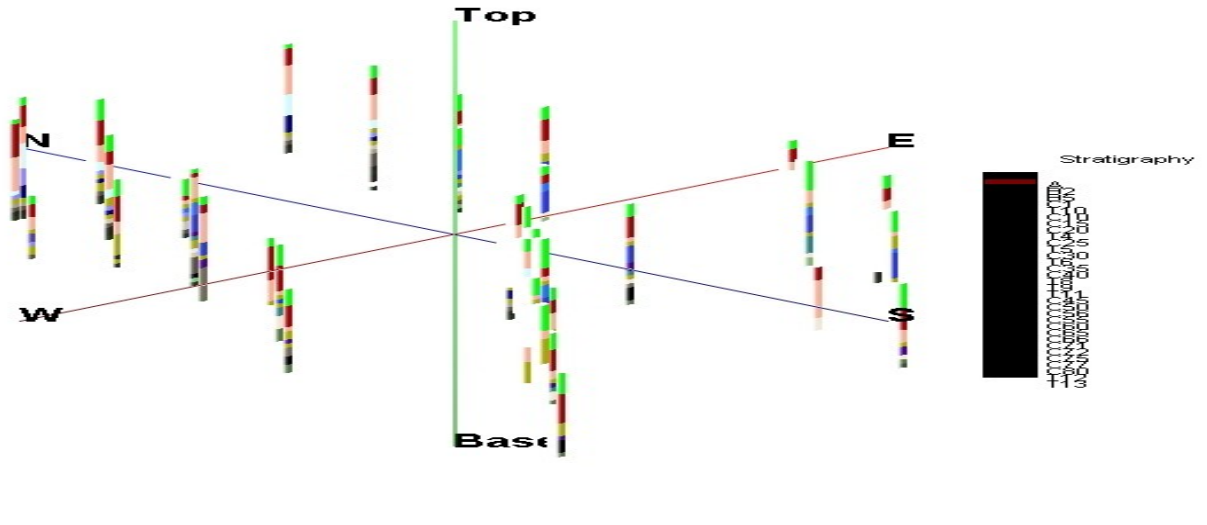
Many of those sites have been excavated since the end of the 70s by an Argentinean research team directed by Ernesto Piana and Luis Orquera.

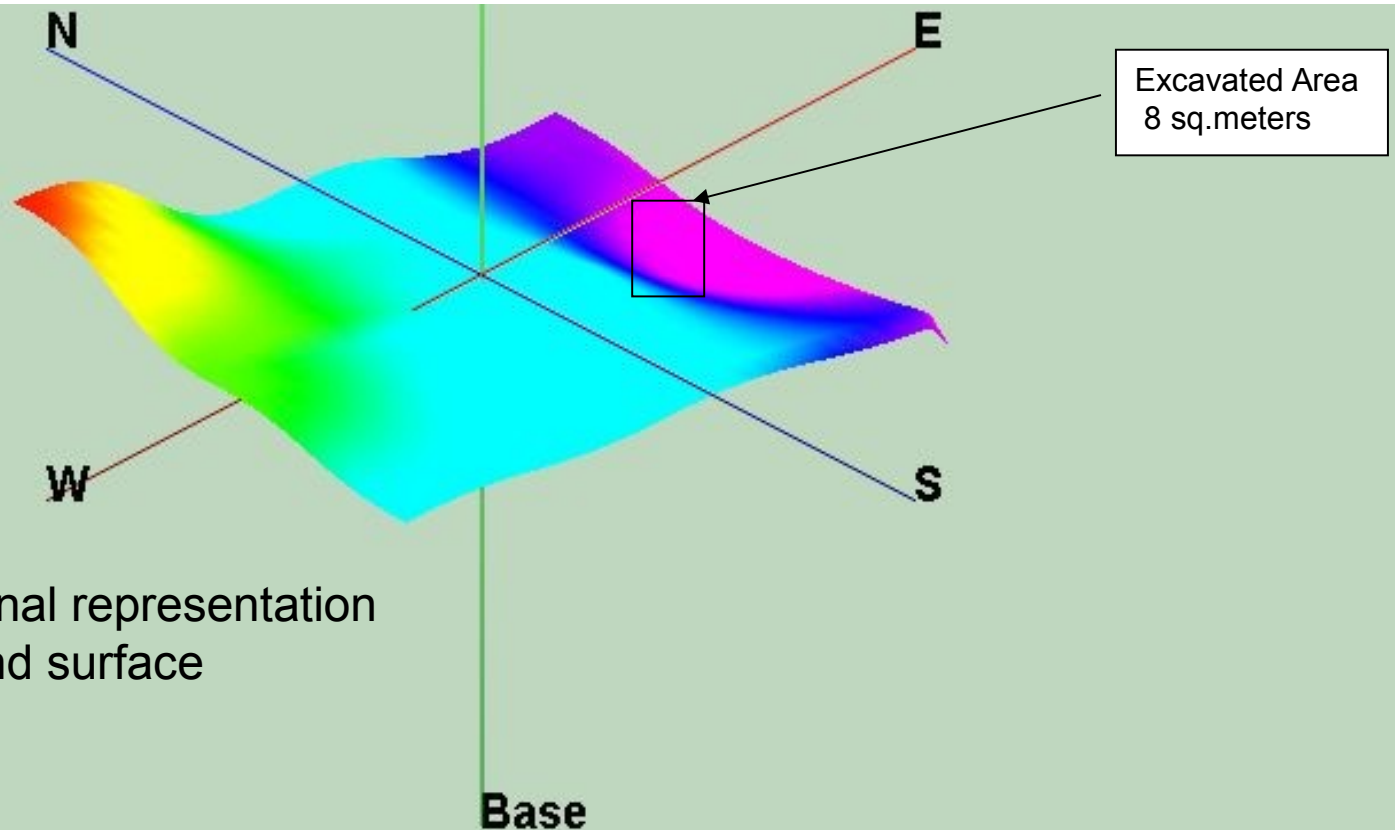
Archaeological Excavations at the Shamakush VIII site (2002)

Archaeological Excavations at the Shamakush VIII site (2002)




Manifold System - [Project1 *]
File Edit View Surface Tools Window Help
TOPOGEN$ 3 *
TOPOGEN$ 3 Shot
TOPOGEN$ 2
TOPOGEN$ 2 Terrain
TOPOGEN$ 3
TOPOGEN$ 3 Terrain
TOPOGEN$
Terrain
320 x 320 pixels
not
Select
[All Pixels]
Add Margin
Apply
Orthographic
30.7544 37.9175
> 1:2000
Float64
320 x 320
Replace
Inicio
Manifold System - [Pr...
20:25

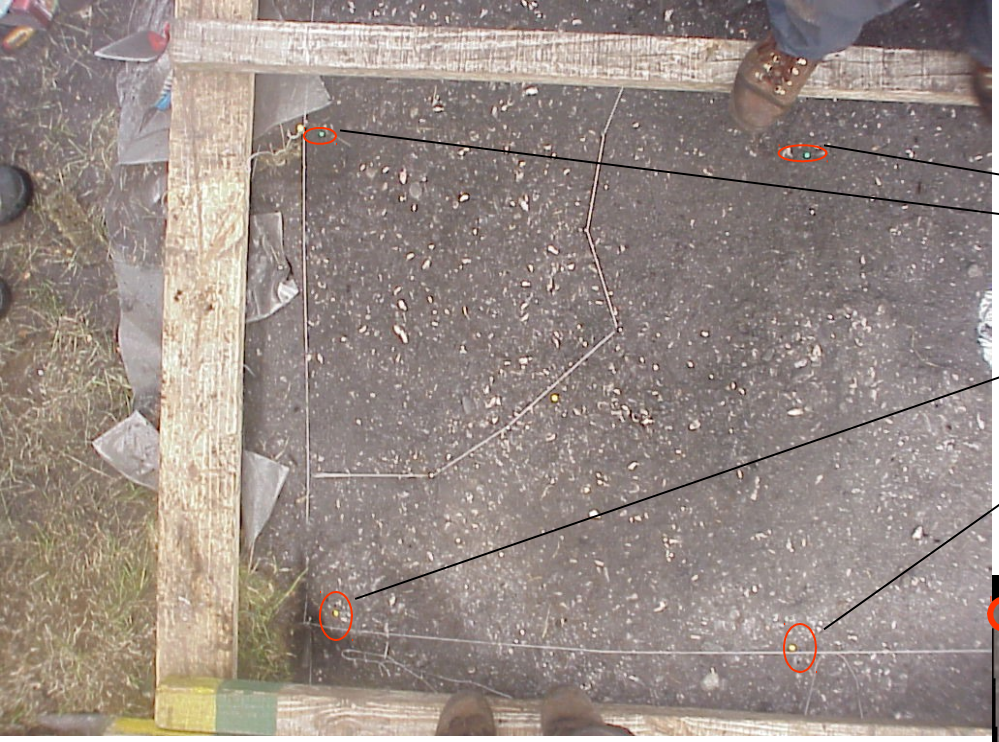




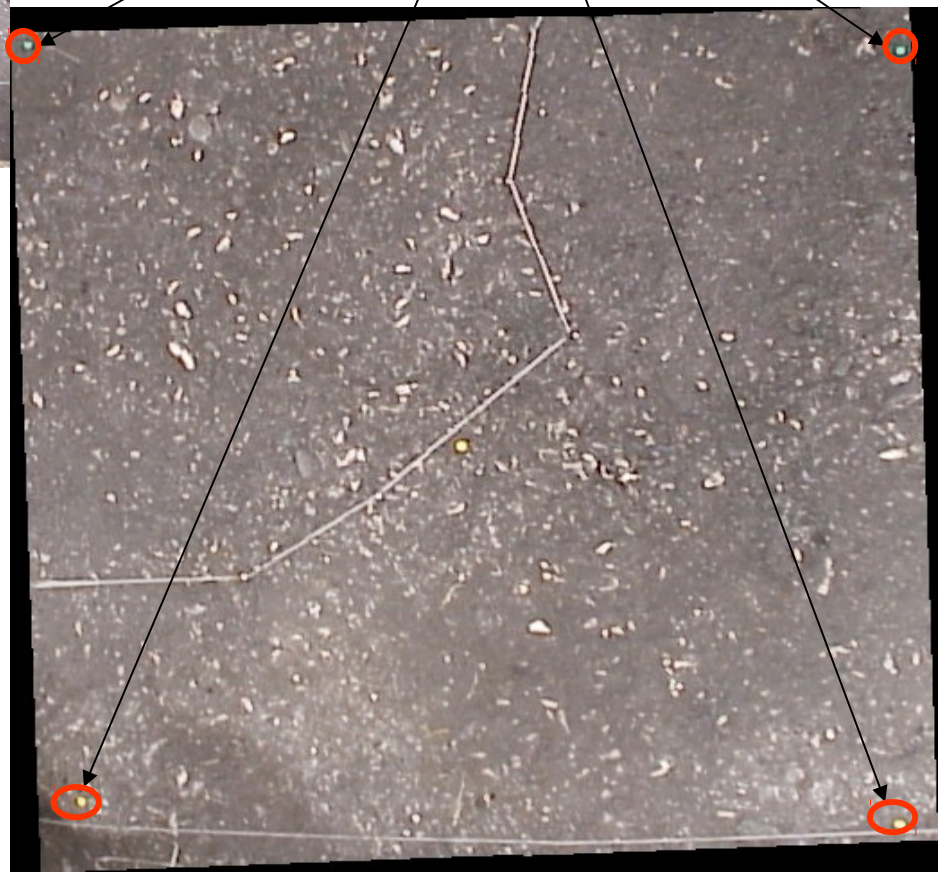
Three dimensional representation of original ground surface

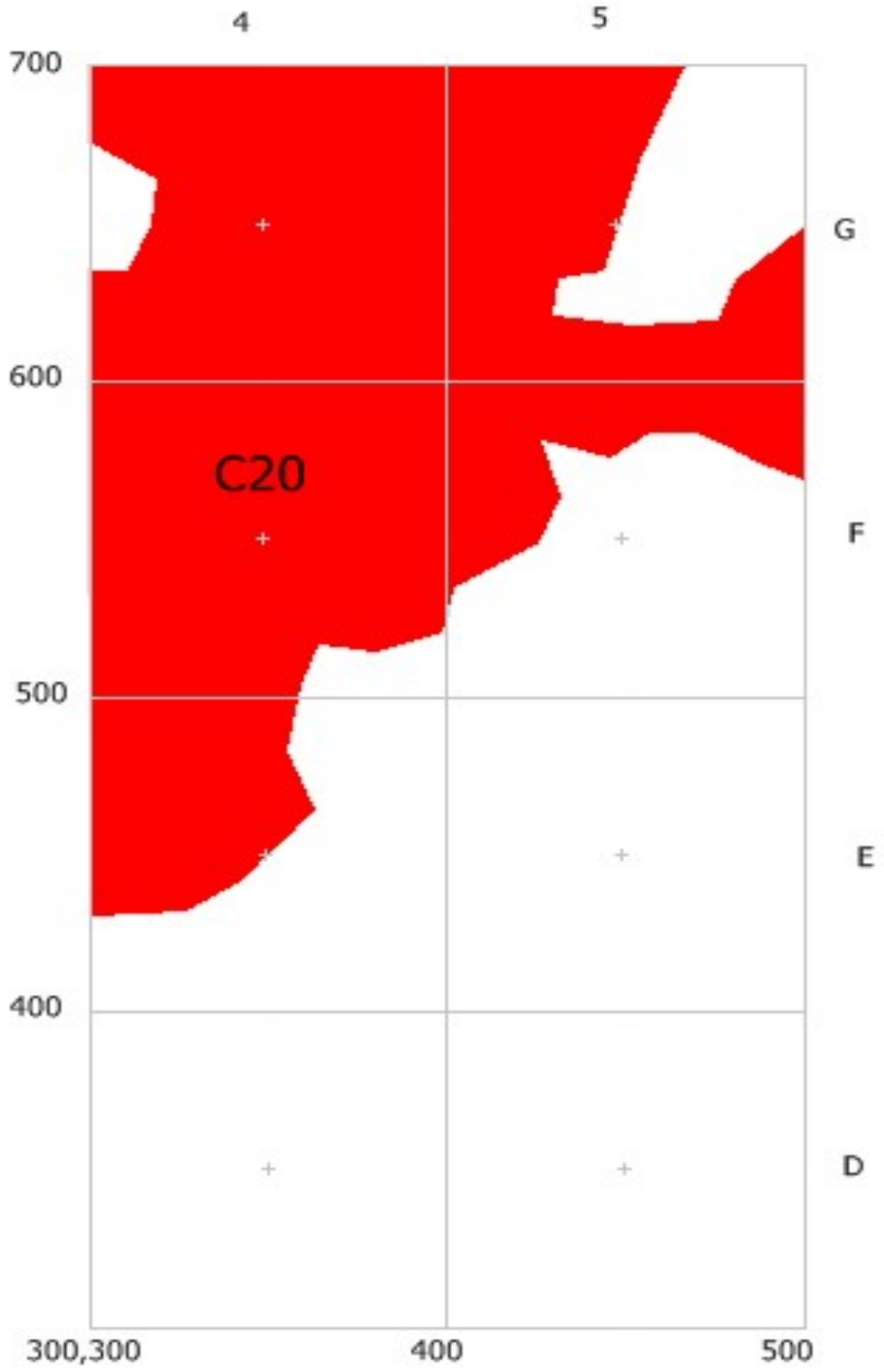
Archaeological Excavations at the Shamakush VIII site (2002)

DOCUMENTING *FORM VARIATIONS*



Control points




4
5
700
600
500
400
G
F
E
D
C20
300,300
400
500

Manifold System - [Shamakusk_8 *]

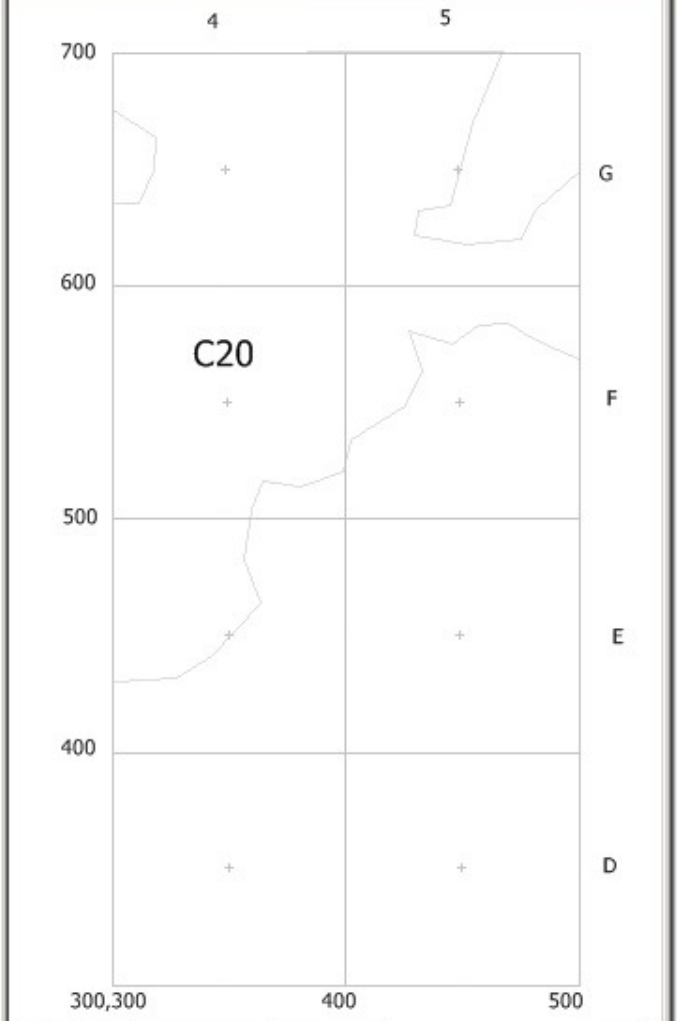
File Edit View Labels Tools Window Help

Tahoma 8

C20 Foto *

C20 Del | Sh8_24 | Sh8_23 | Sh8_22 | Sh8_20 | Sh8_21

Shamakush VIII *



Puntos Foto | Cuadricula 02 | Labels Cuadricula | A Del | B

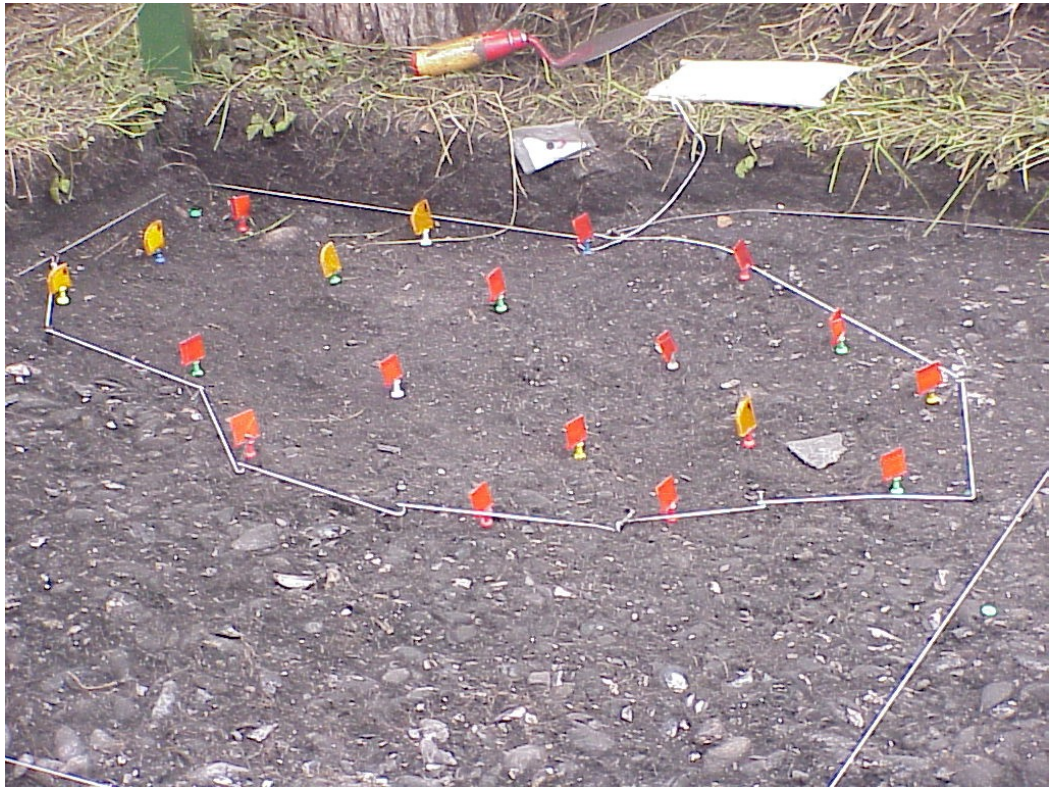
- Sh8_114
- Sh8_20
- Sh8_21
- Sh8_22
- Sh8_23
- Sh8_24
- Sh8_89
- Sh8_90
- Sh8_91
- Sh8_92
- Sh8_93
- Sh8_94
- Sh8_95
- Sh8_96
- Sh8_97
- Sh8_98
- Sh8_99
- C20 Foto
- C72 Foto
- C77 Foto
- C77 2
- AE1
- AE2
- AE3
- AE4
- AE6
- B2
- C1
- C10
- C15
- C20
- C25
- C30
- C35

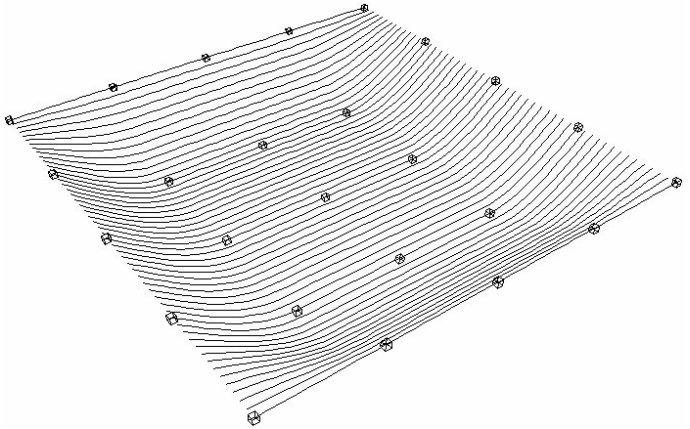
Map 6 layers

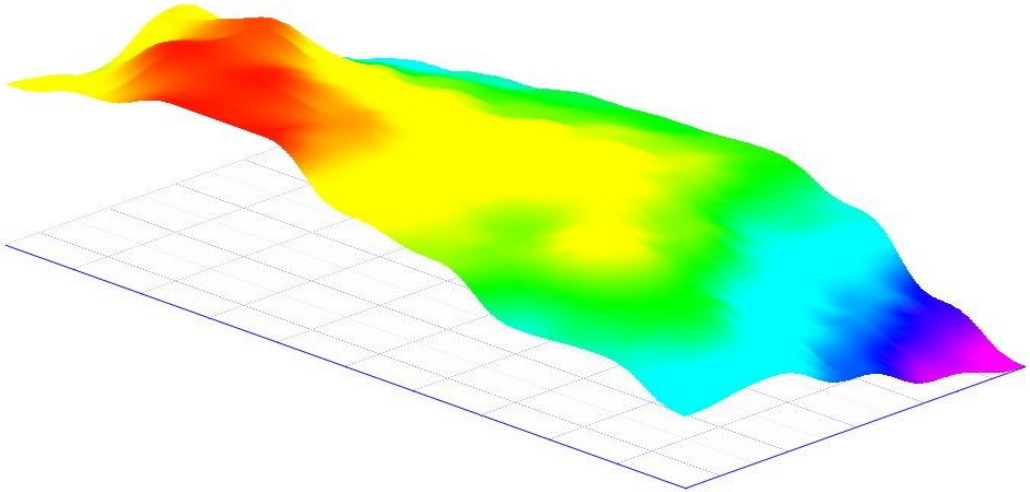
not Select Apply

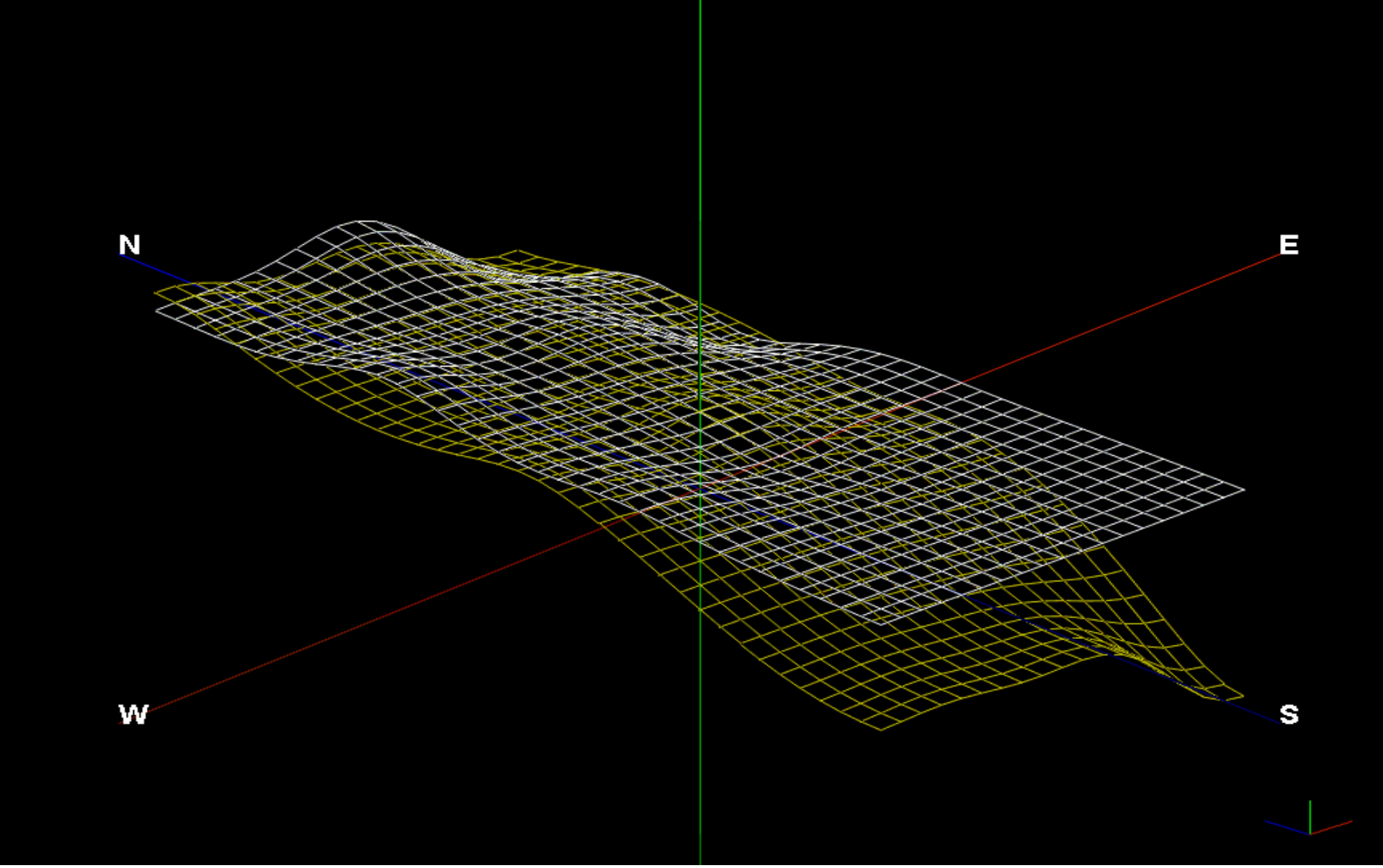
Zoom to rectangular area | Orthographic | 5.1956 3.8758 | ~ 1:26 | Replace | Zoom

Inicio | Manifold System - [Sh... | Adobe Photoshop | ES | 19:05

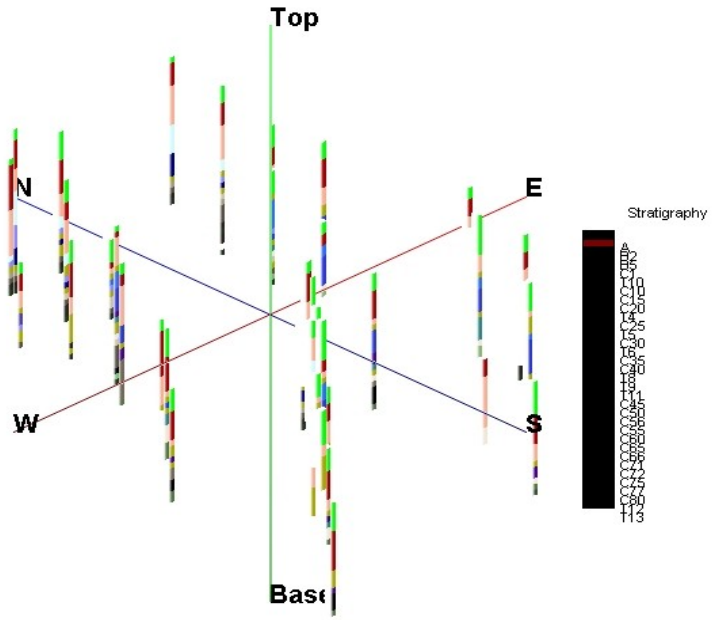







N
E
W
S

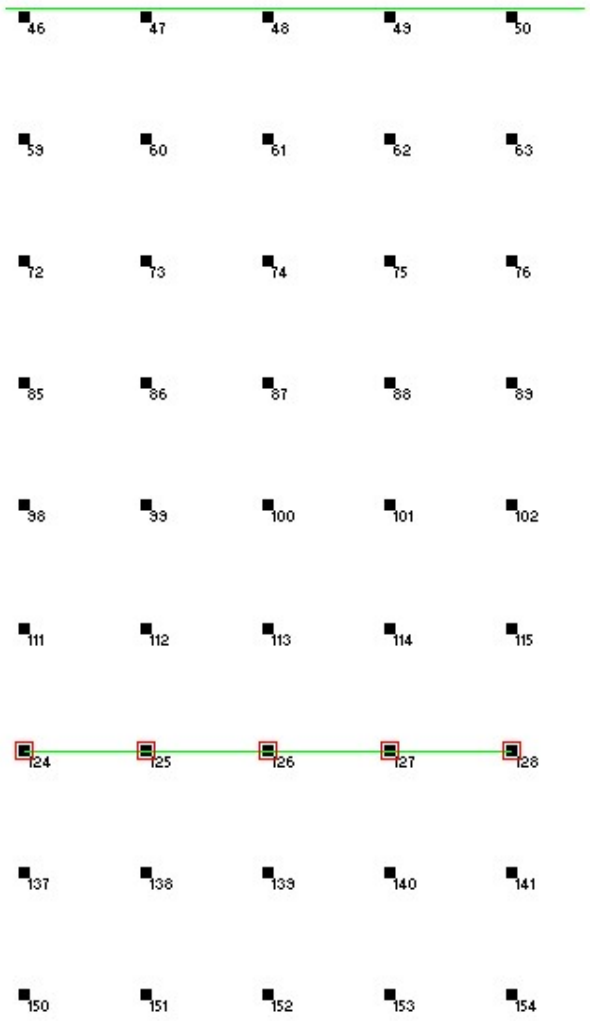
X	Y	C1	C2	U1	U2	C3
12.3	52.6	51.3	32.4	23		12.6
15.6	63.6	50.6	33.5	22.1		10.1
16.2	65.1	51.2	36.1	24.9		9.5
17.6	66.3	53	33.2			11.6
18.4	70.2	52.6	33.4			12.5
19.7	71.3	49.8	35		22.5	11.1
20.1	72	52.3	32.1		22.5	14.6

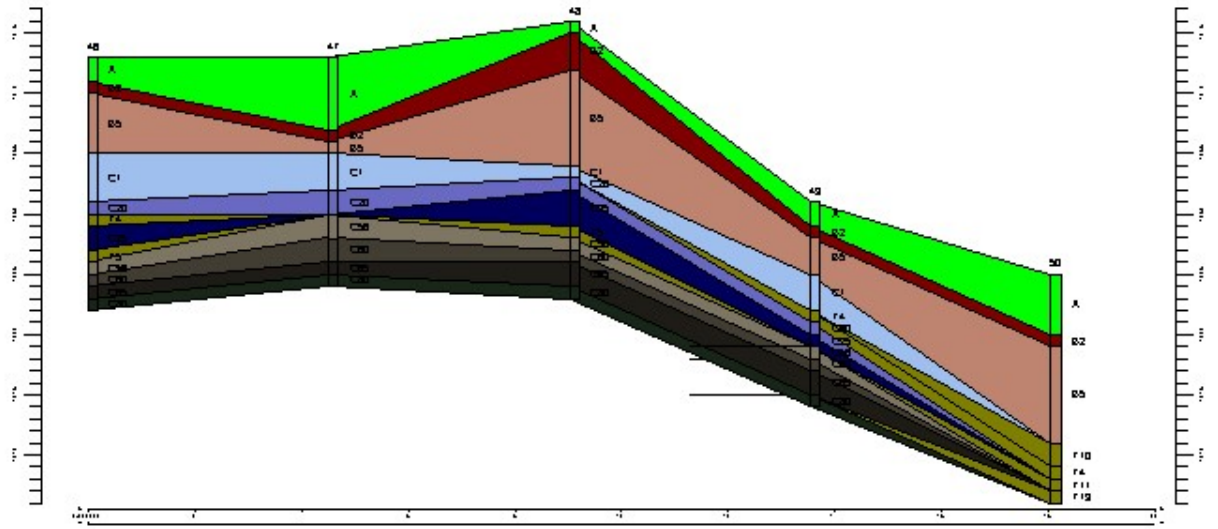


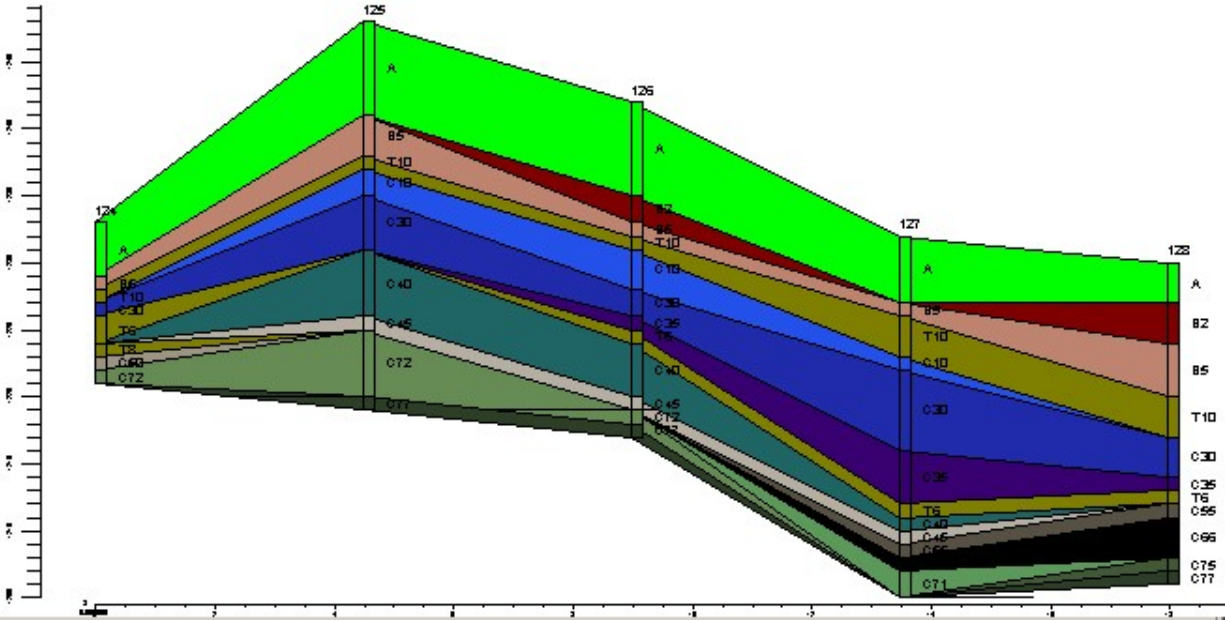
RockWorks/2002 Borehole Manager (Log = C:\SHAMAKUSH 8

Select Boreholes ...

Options Edit View Help



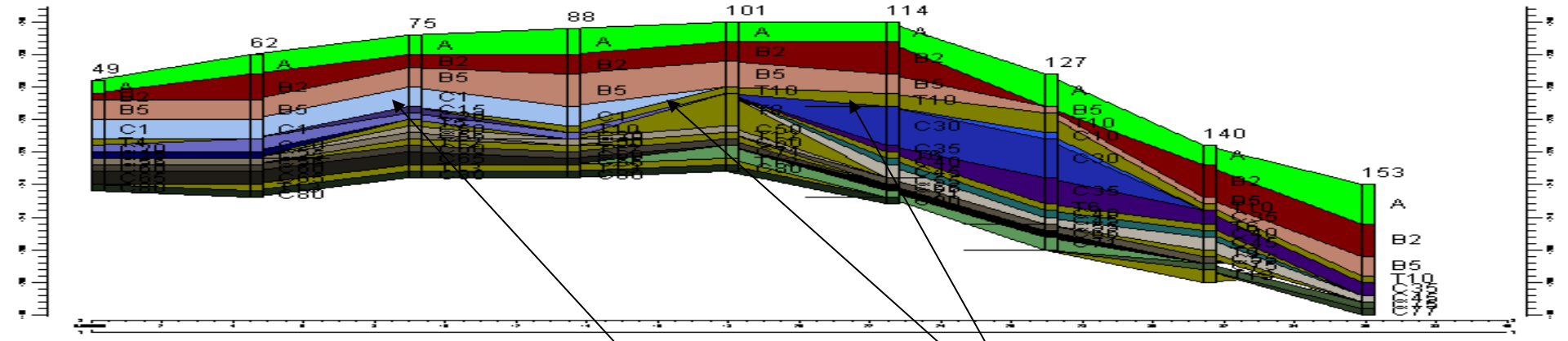




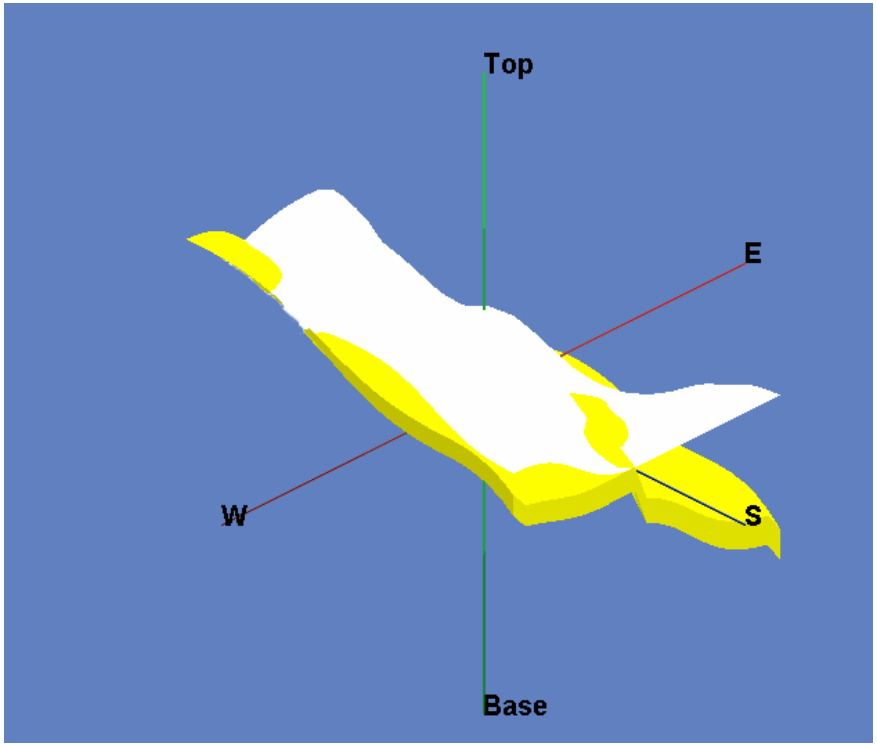
X = 59.488000 Y = 26.076800

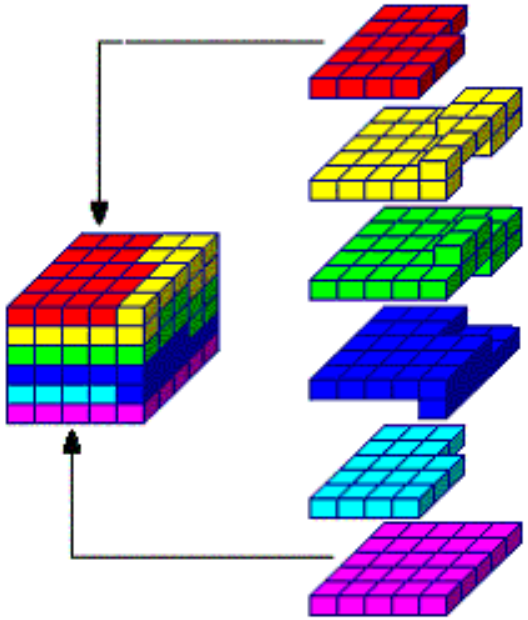
Ok Cancel

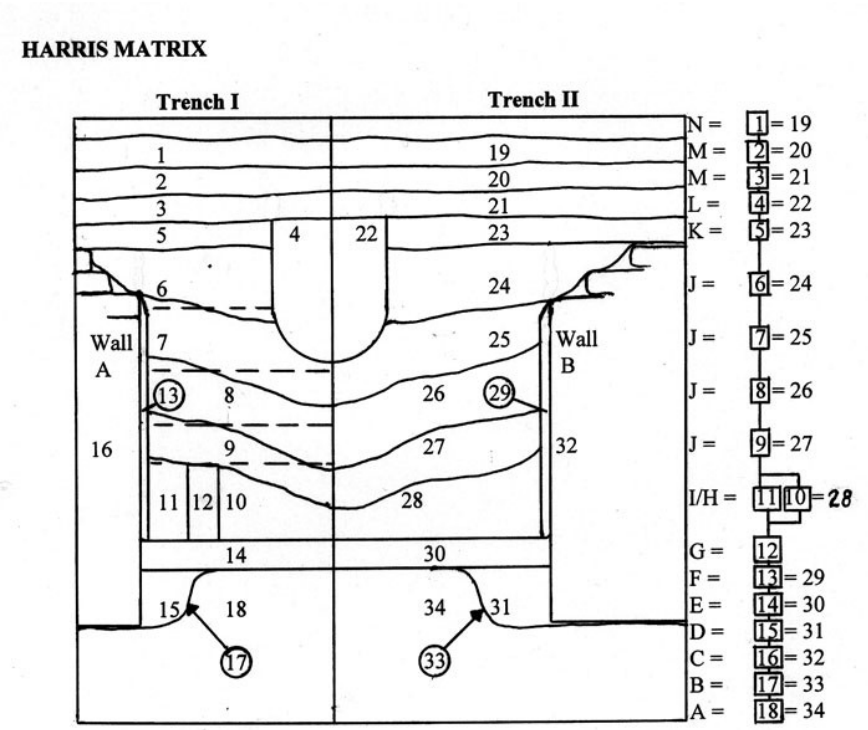
Inicio RW2002 Tutorials Adobe Photoshop RW2002 RW2002 Tutorials Microsoft Excel... ES 20:17

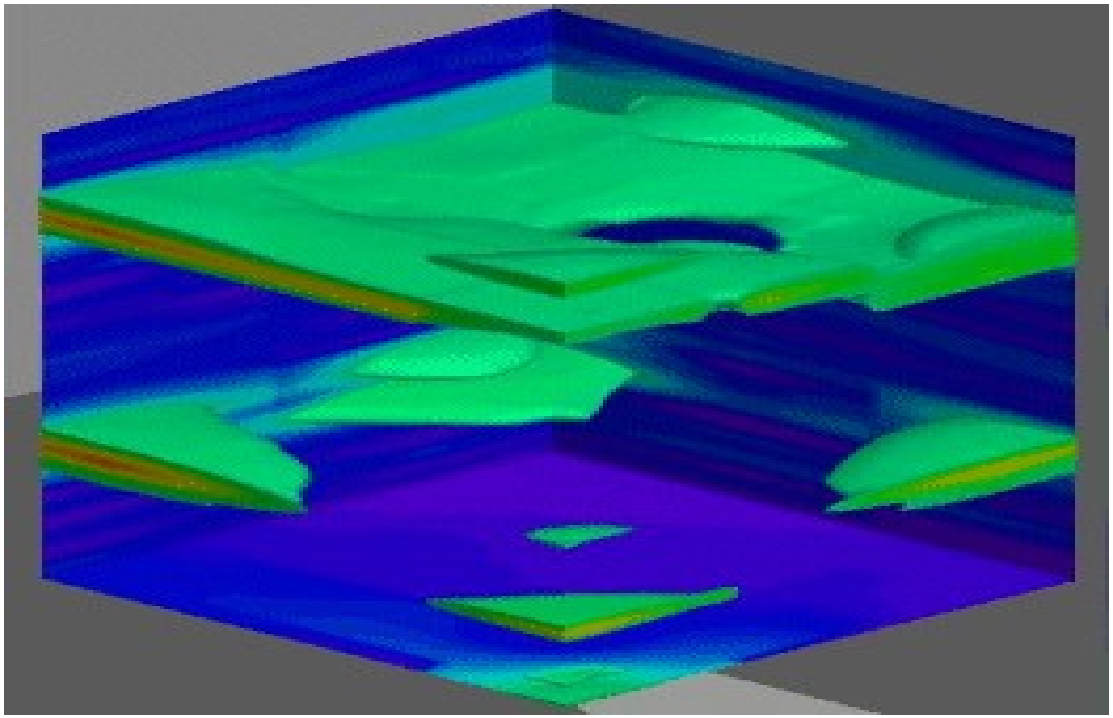


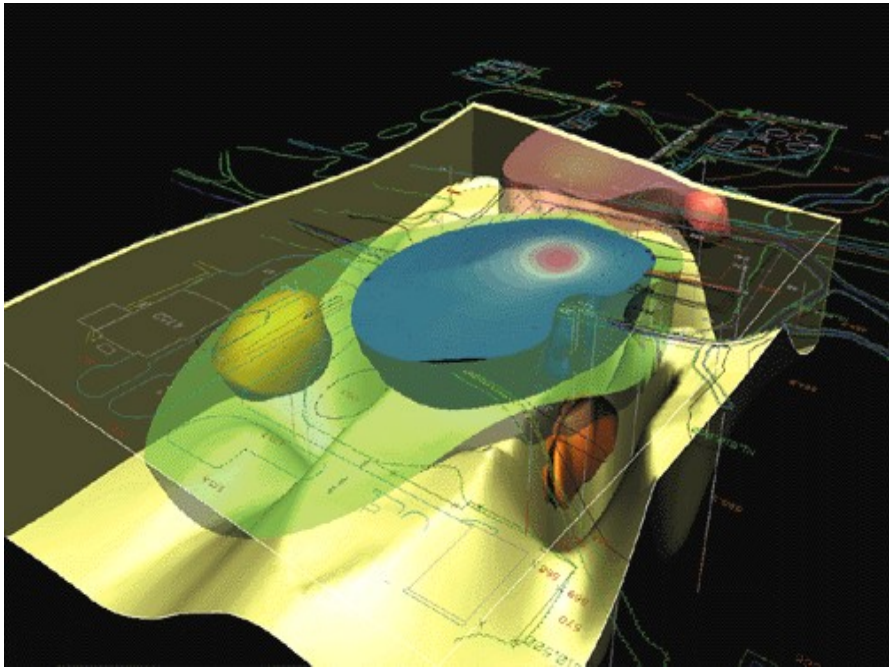
Relationship between C1 (white) and T10 (yellow)

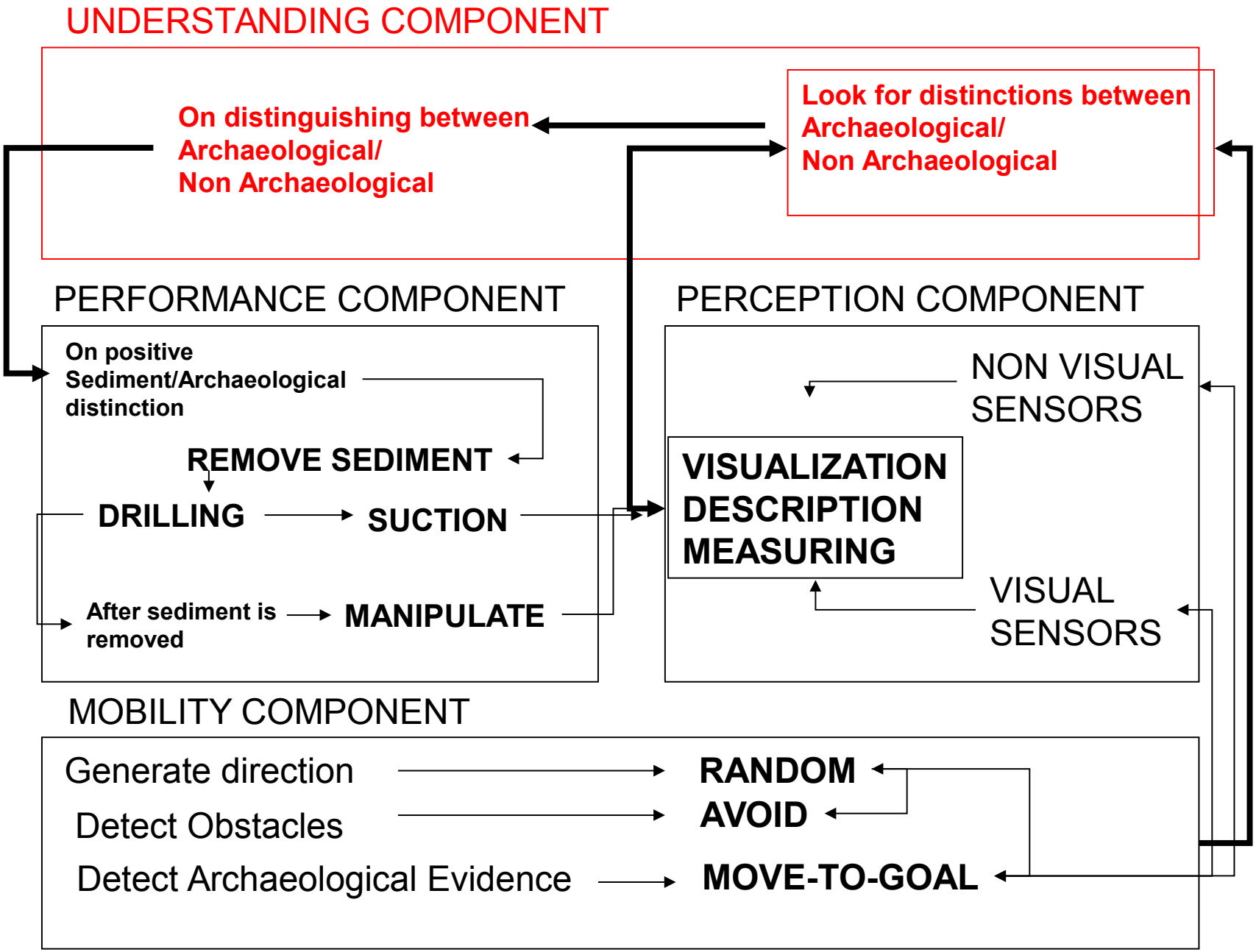






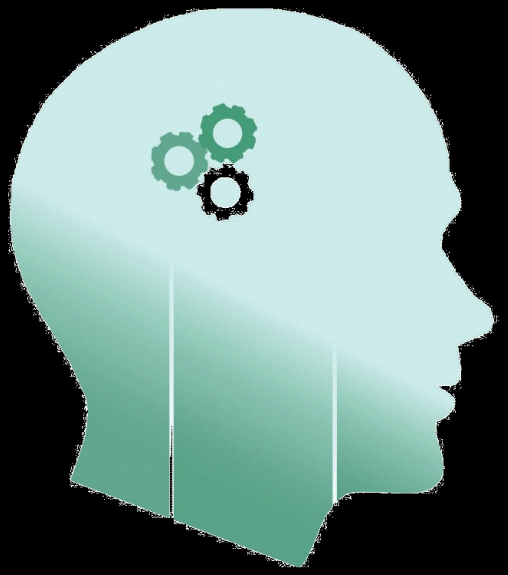


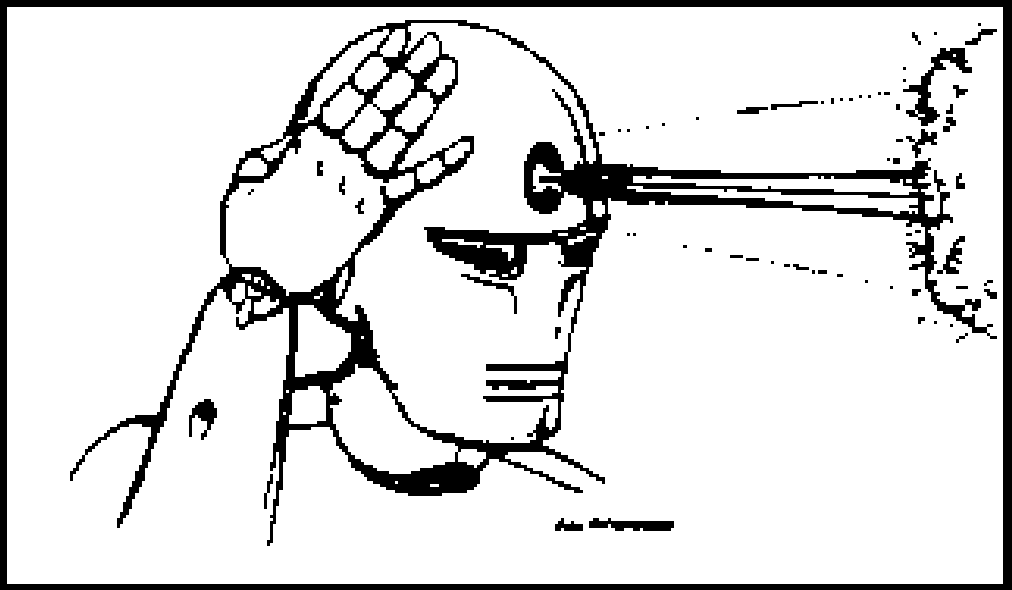



UNDERSTANDING COMPONENT
On distinguishing between Archaeological/ Non Archaeological
Look for distinctions between Archaeological/ Non Archaeological
PERFORMANCE COMPONENT
On positive Sediment/Archaeological distinction
REMOVE SEDIMENT
DRILLING
SUCTION
After sediment is removed
MANIPULATE
PERCEPTION COMPONENT
NON VISUAL SENSORS
VISUALIZATION
DESCRIPTION
MEASURING
VISUAL SENSORS
MOBILITY COMPONENT
Generate direction
Detect Obstacles
Detect Archaeological Evidence
RANDOM
AVOID
MOVE-TO-GOAL

Can a computer “explain”?

MACHINES WHO THINK. An impossible story?



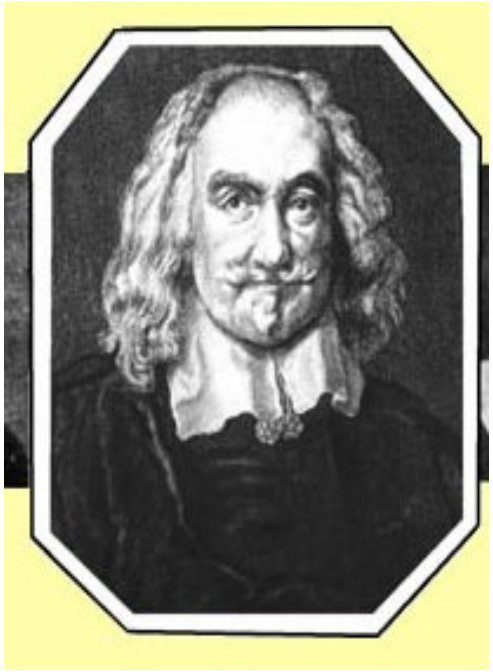


Raimon Lull (13th. century)

He suggested a logic machine for discovering nonmathematical truths through combinatorics,

Thomas Hobbes (1588-1679)

"by ratiocination, I mean *computation"*



Gottfried Wilhelm von Leibniz (1646-1716)

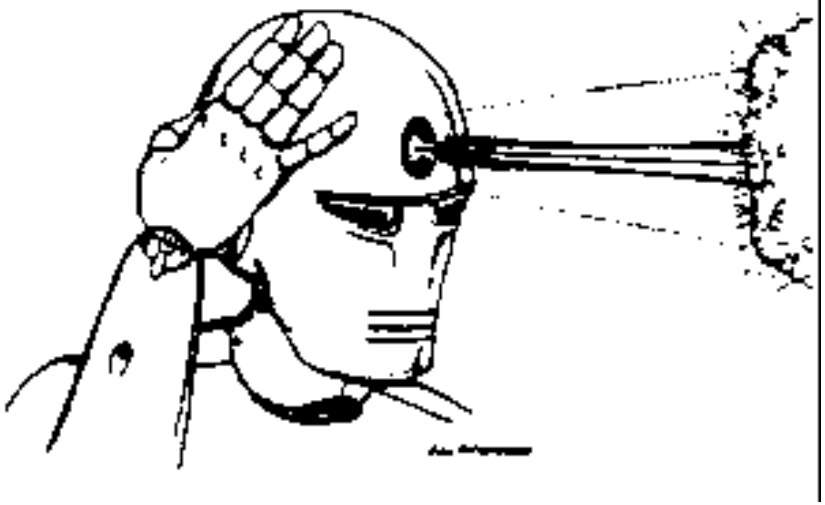
He seemed to see the possibility of mechanical reasoning devices using rules of logic to settle disputes

Julien Offray de La Mettrie (1709-1751)

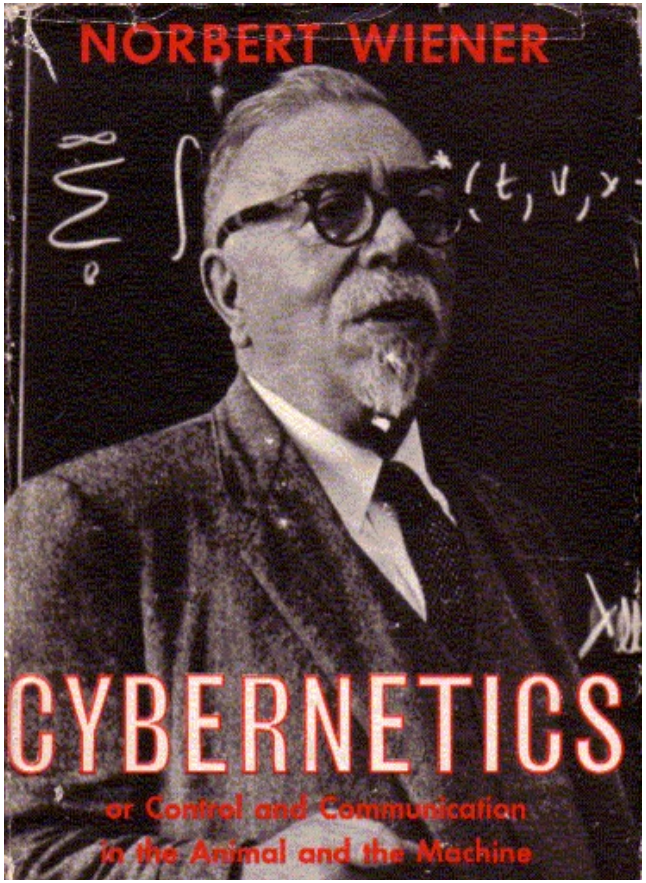
"Man is a machine"

Bertrand Russell (1914)

“There is no theoretical limit to what can be done to make mechanical records analogous to what a person would perceive if he were similarly situated"



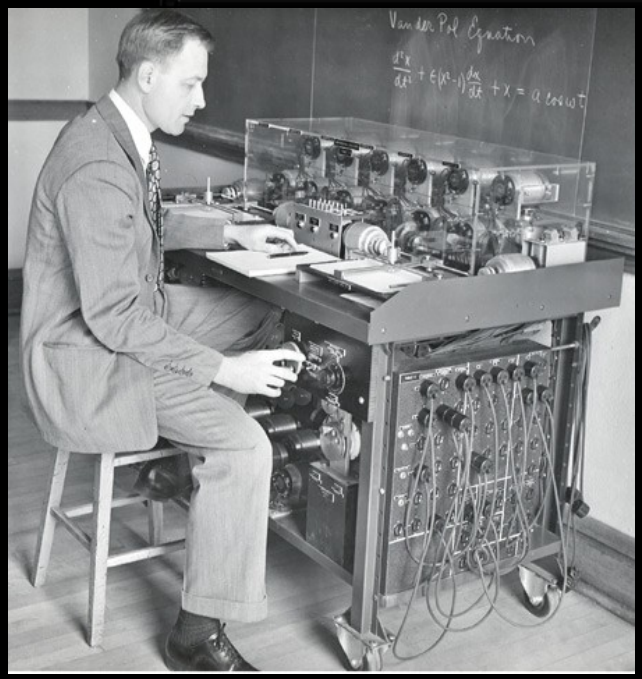
Cybernetics 1940

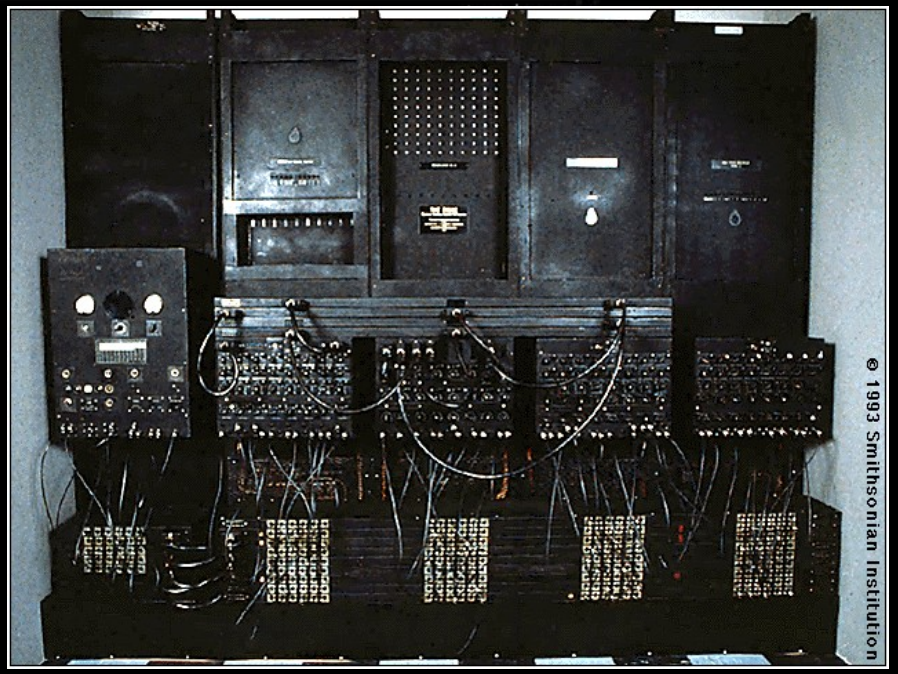


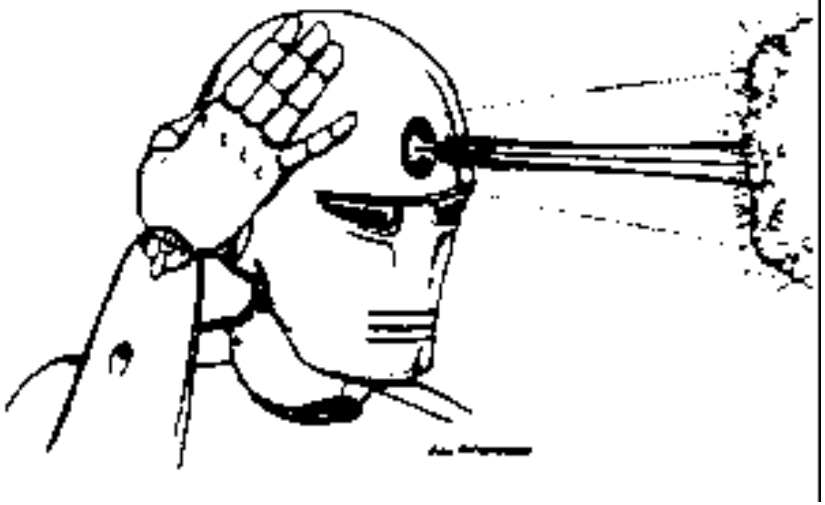
Cybernetics preceded Computational Intelligence as a discipline addressed to the discovery of unifying principles between cognitive faculties and the behavior of things.

World's First Computer

Print Delete





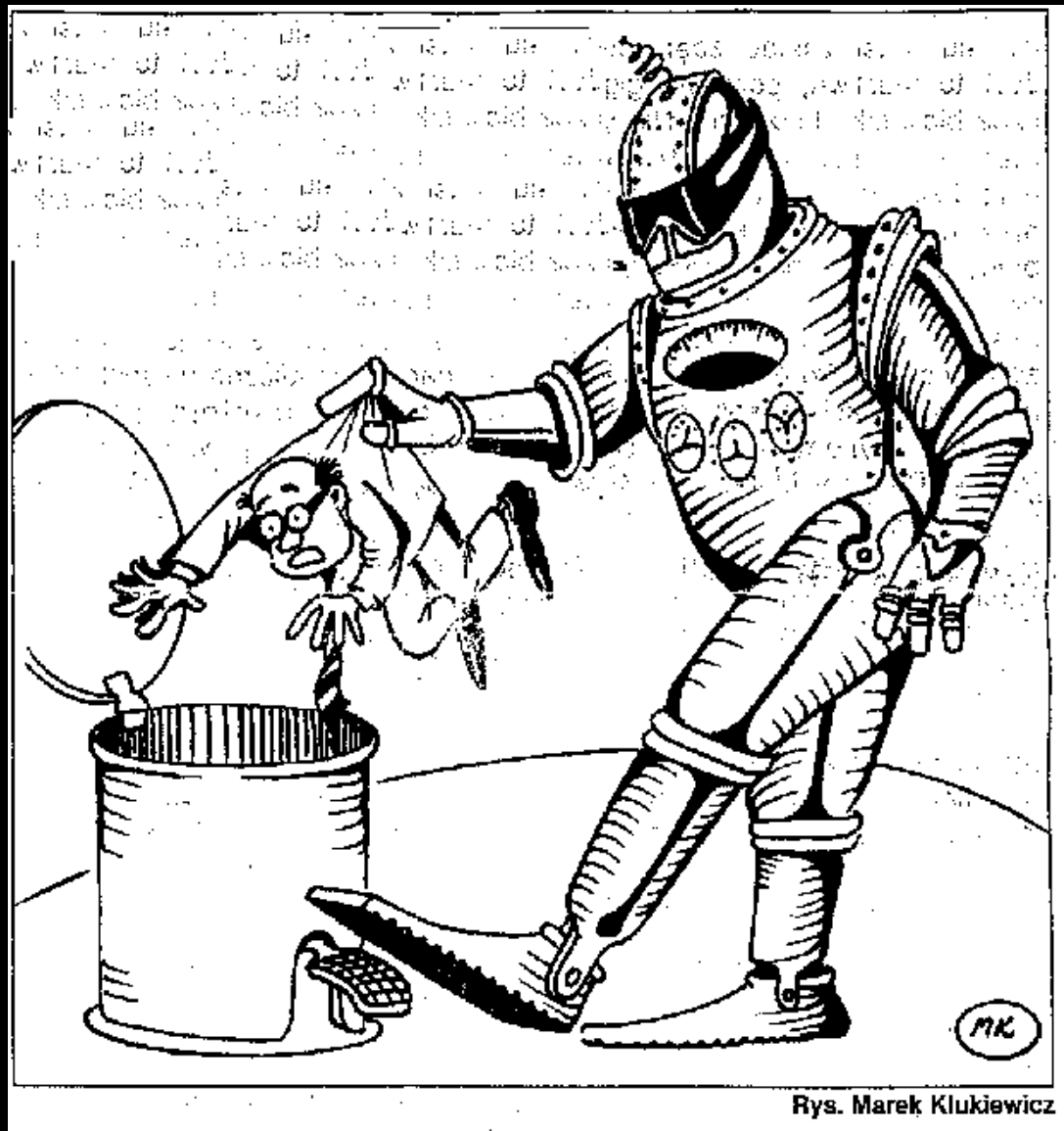


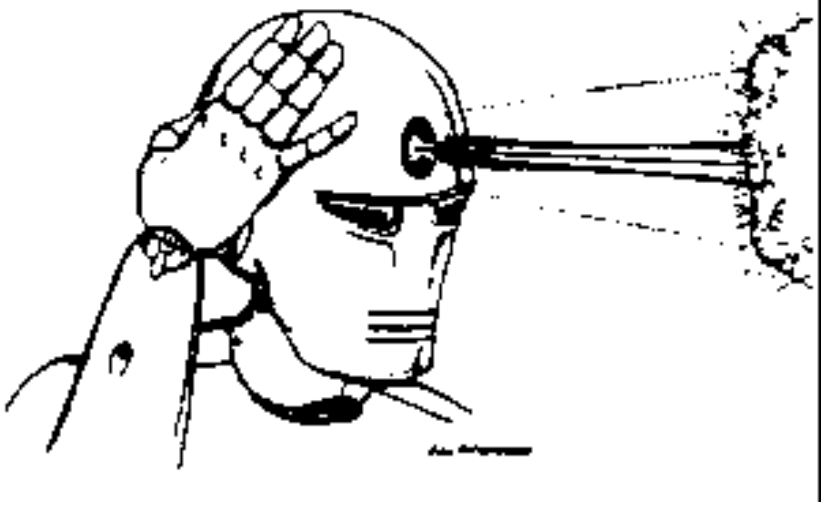
“Artificial Intelligence” 1956

“if a machine can do a job,
then an automatic calculator
can be programmed to simulate
the machine” (J. McCarthy).

“Machines will be capable of doing any work a man can do by 1985”.

Herbert Simon, in 1965



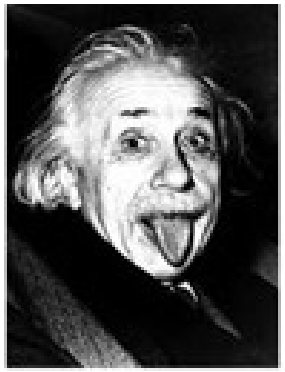


“Expert Systems” 1968

A computer system that is programed to mimic the procedures and decisions that "experts" make

A domain specific knowledge base combined with an inference engine that processes knowledge encoded in the knowledge base to respond to a user's request for advice

Introduccion:
What is an Expert System?

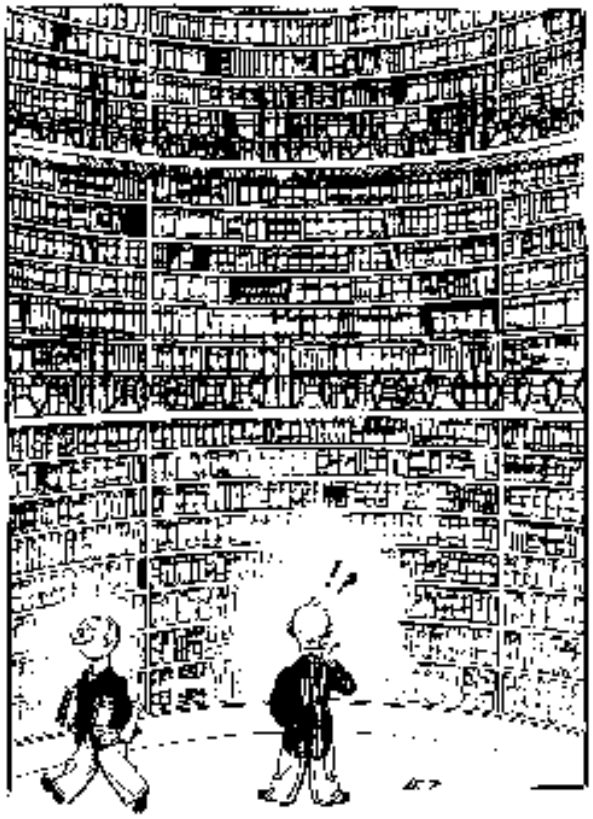


+

= EXPERT SYSTEM

The primary goal of expert systems research is to make expertise available to decision makers and technicians who need answers quickly

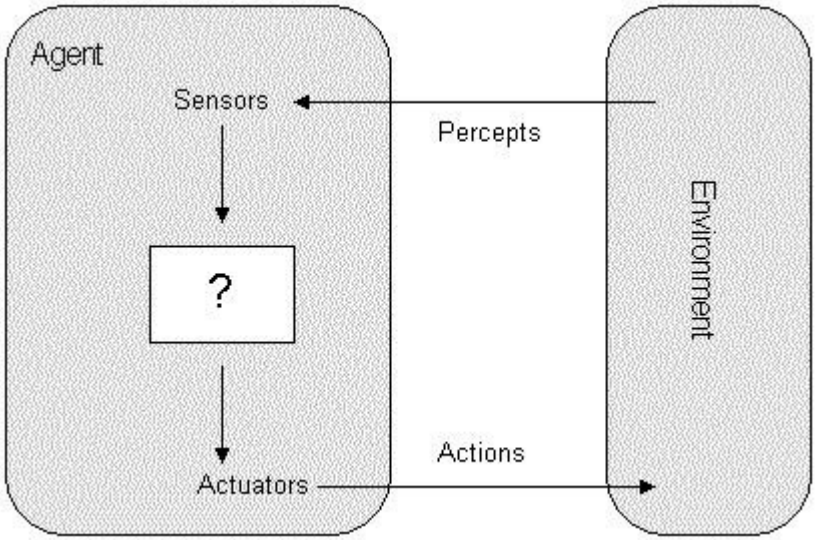
Today's expert systems deal with domains of narrow specialization. For expert systems to perform competently over a broad range of tasks, they will have to be given very much more knowledge



Information is viewed as something that can be stored, coded, matched, and displayed. That means that information is derived from external objects and flows into the system via the senses. It is denotational because it is an *encoding*. The robot's memory is just a storehouse of denotational encodings.

Knowledge bases

Knowledge for an expert system. is encoded in condition-actions pairs.

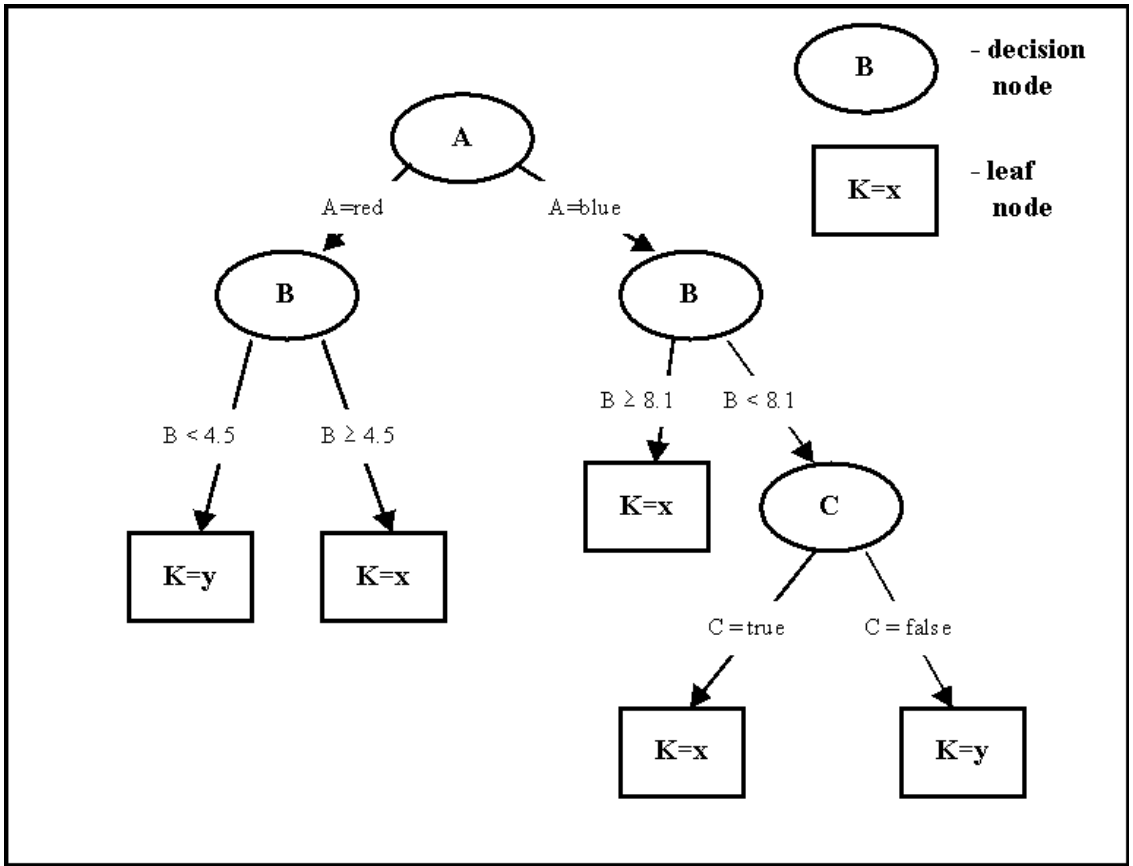


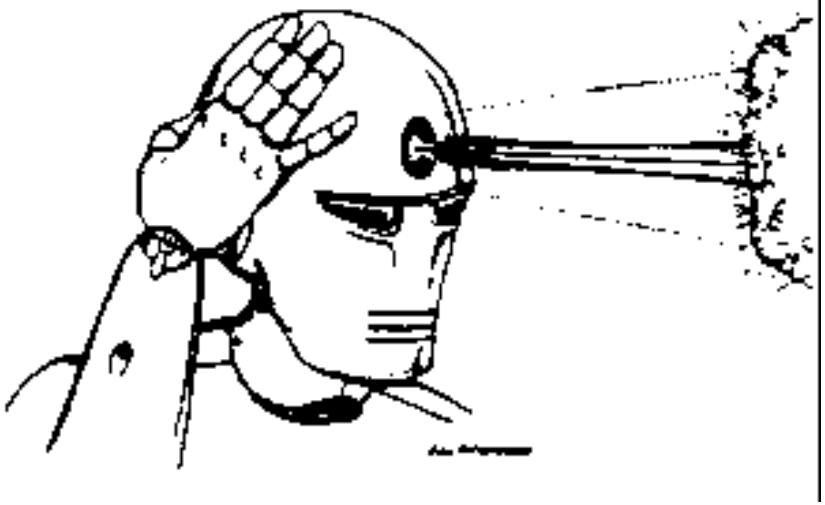
Rules

- IF FEATURE1 = true
  (object O has Feature1)
  And (If Feature1 then Concept X) = true
  And GOAL= G
- THEN CONCEPT X = true
  (the presence of object O allows the use of Concept X in the circumstances defined by Object O, if and only if your goal to achieve was G)

Knowledge bases

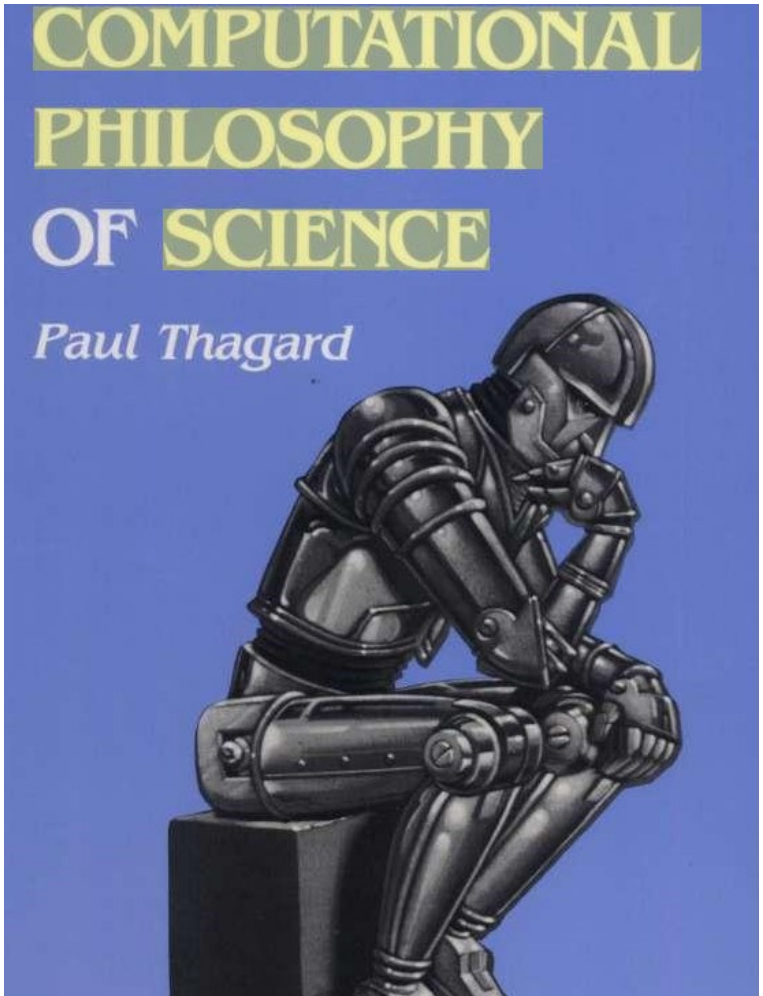
Condition-actions pairs can be implemented as decision trees



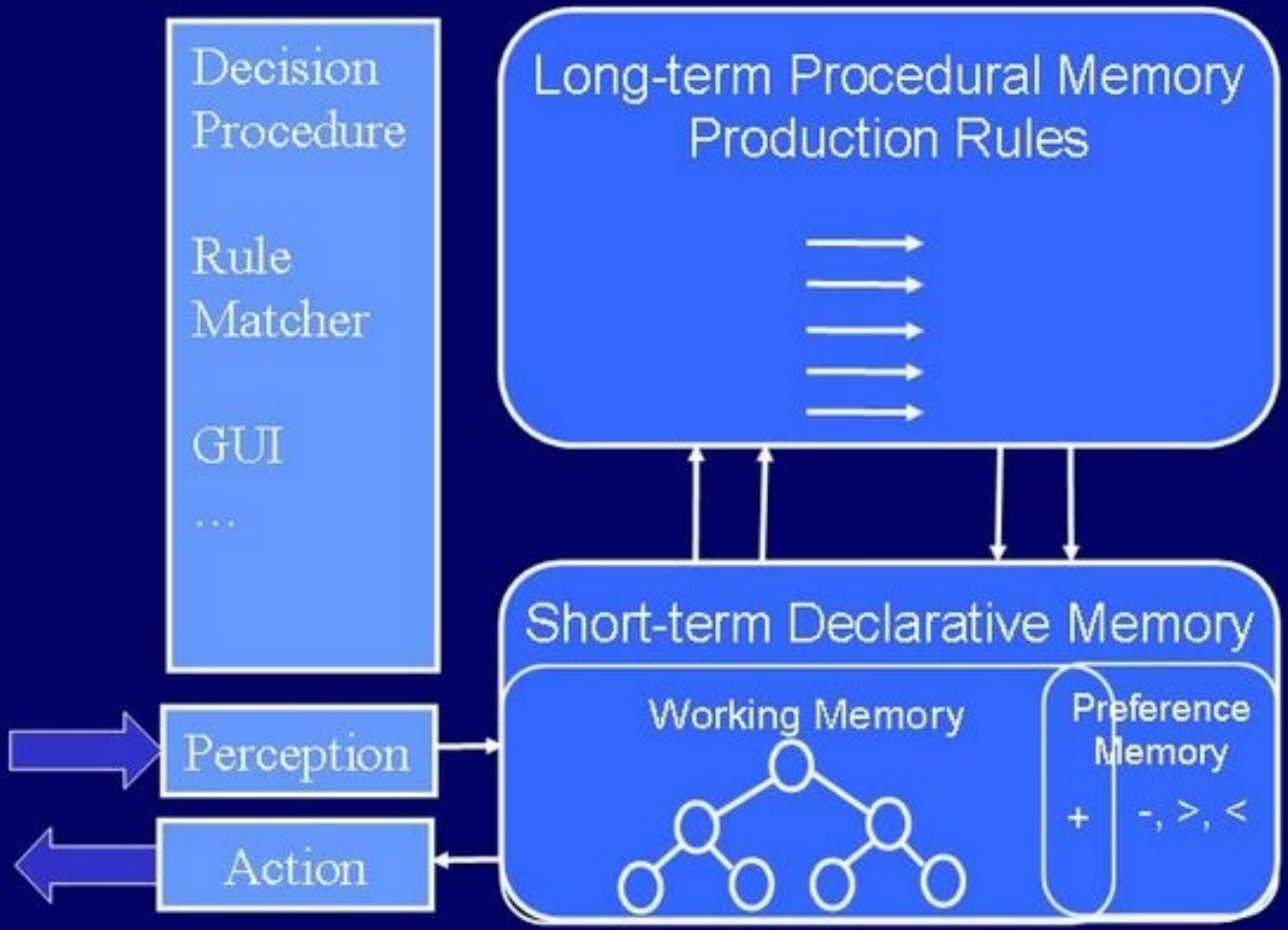


“Computational Philosophy of Science”
1980s

“Scientific reasoning can described in terms of problem solving search”.



THINK(rationally), PERCEIVE-EXPLAIN



Scientific theory as a Computer Program

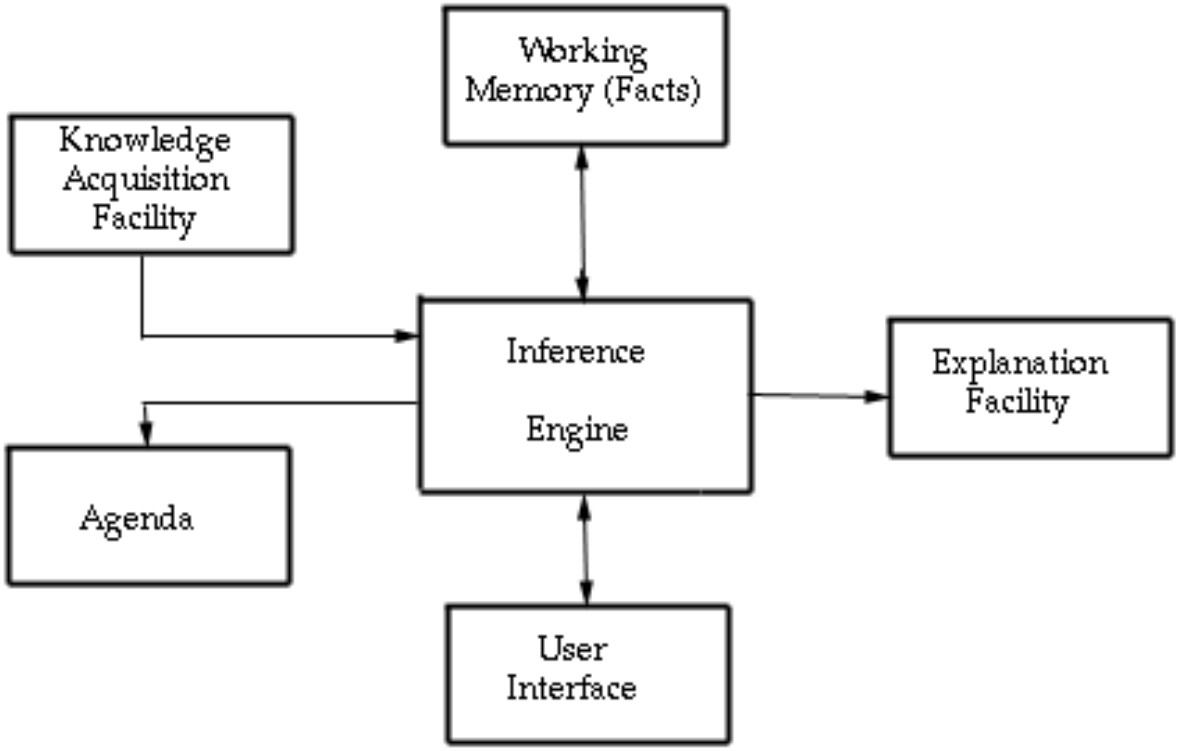
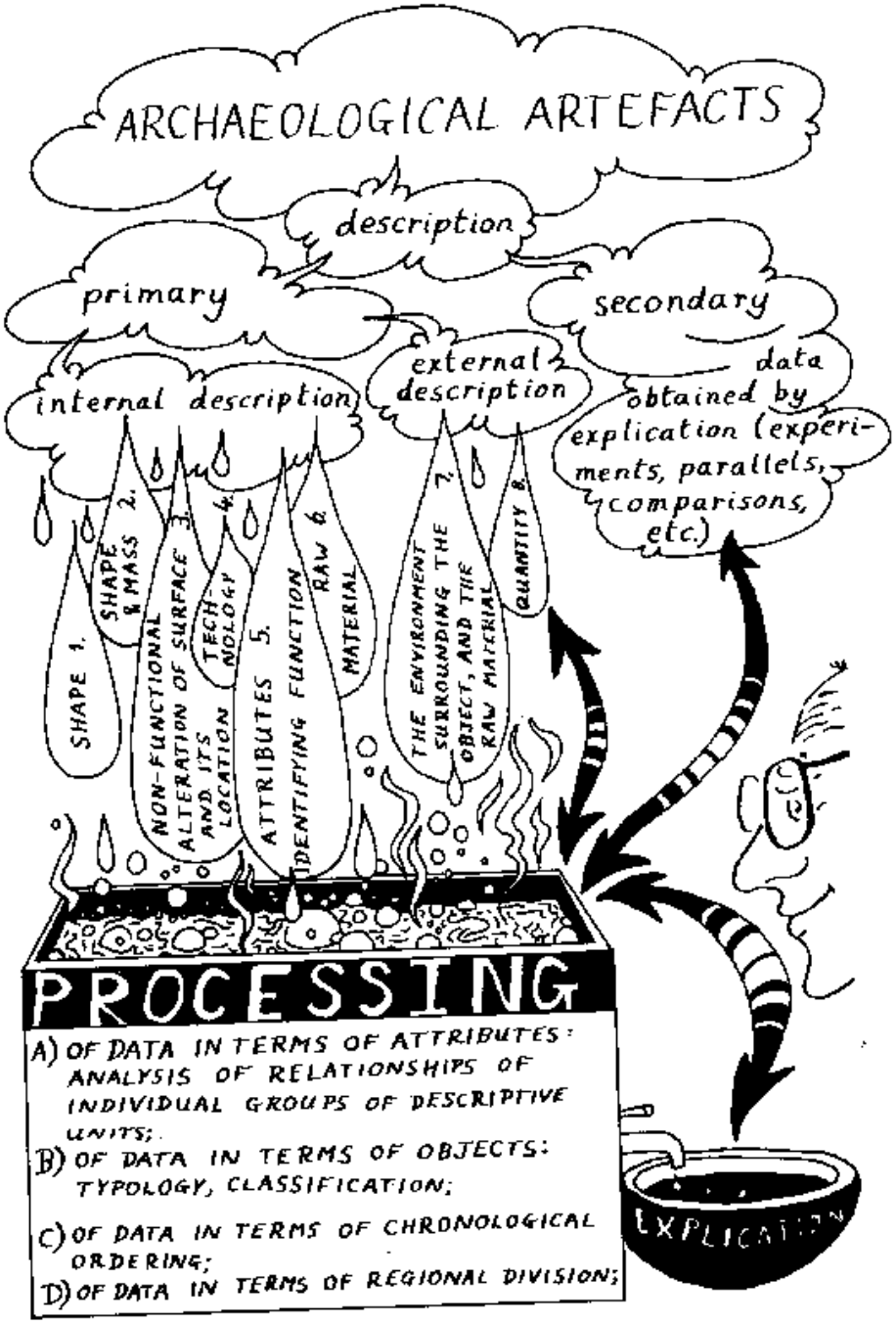


Figure 4.2. - Components of an Expert System.

Come back to Archaeology….



1965

New Archeology and the Need of computers for Archaeological Inference

CYBERNETICS IN ARCHAEOLOGY
1970s

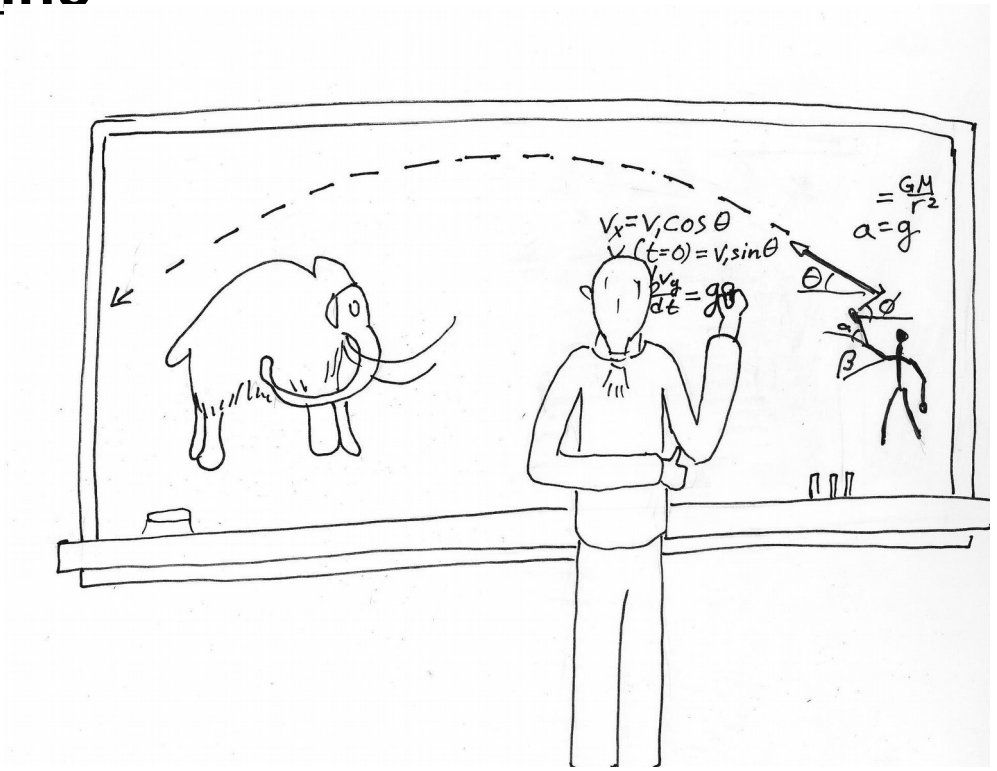
"Human Society should be studied as if it was a **machine**"

USA, UK:
"New Archaeology",
Binford et al.
David Clarke

"The Archaeologist acts **mechanically** when explaining observed data"

France,
Jean Claude Gardin
Mario Borillo

Human Society should be studied as if it was a **machine**”



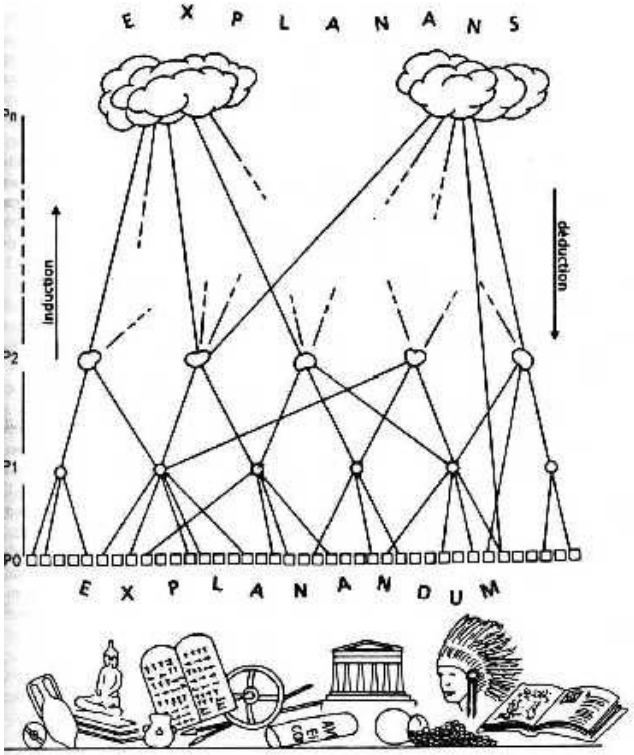
David Clarke:

- concept description and quantification using descriptive statistics
- relationship analysis concepts using inductive statistics
- identification of regularities in complex data in terms of isomorphic systems of symbols arranged in axiomatic schemes, models or calculi.

The Archaeologist acts **<u>mechanically</u>** when explaining observed data

Jean Claude Gardin:

"Une Archéologie Théorique"
(1979)

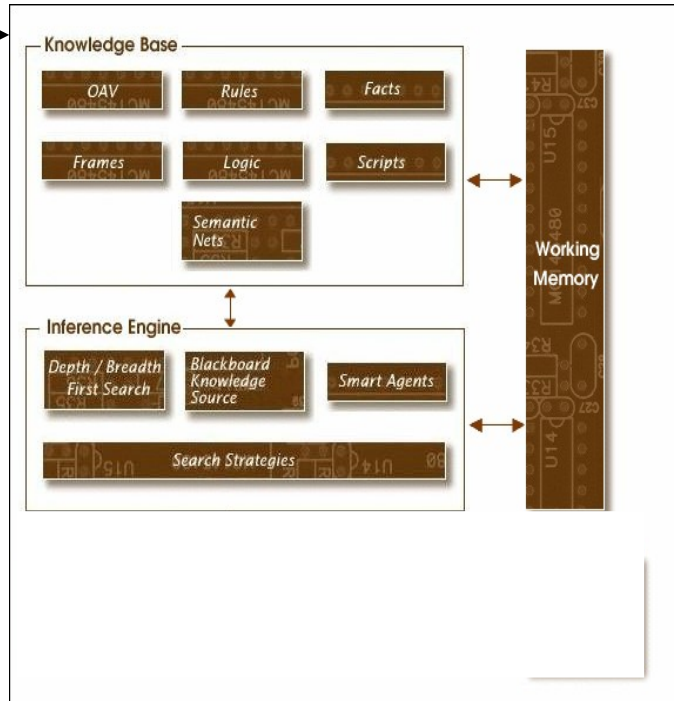


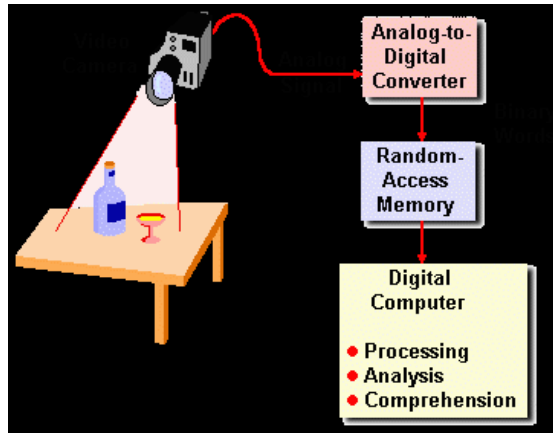
Jean Claude Gardin

	Logicist analysis	*Expert systems*
Semiologic	Database (P_o)	Fact base
Representation	expressed in terms of a scientific language (descriptive "code")	expressed in terms of a computer language (programming)
Information Processing	Re-write operations P_i --> P_{i+1} . Ordered in inductive or deductive chains	Production Rules IF p **THEN** q organized in a cascade linking

Expert Systems in Archaeology

EXPLANATIONS





DATA

Rules

- If (x,y,z) are proper empirical features of Object F1
  And (v,w) are proper definition terms of Concept F
  Or there is some contextual similarity between F and F1
- Then F1 activates F
  Object (F1) is an instance of Concept (F)

EXAMPLES:

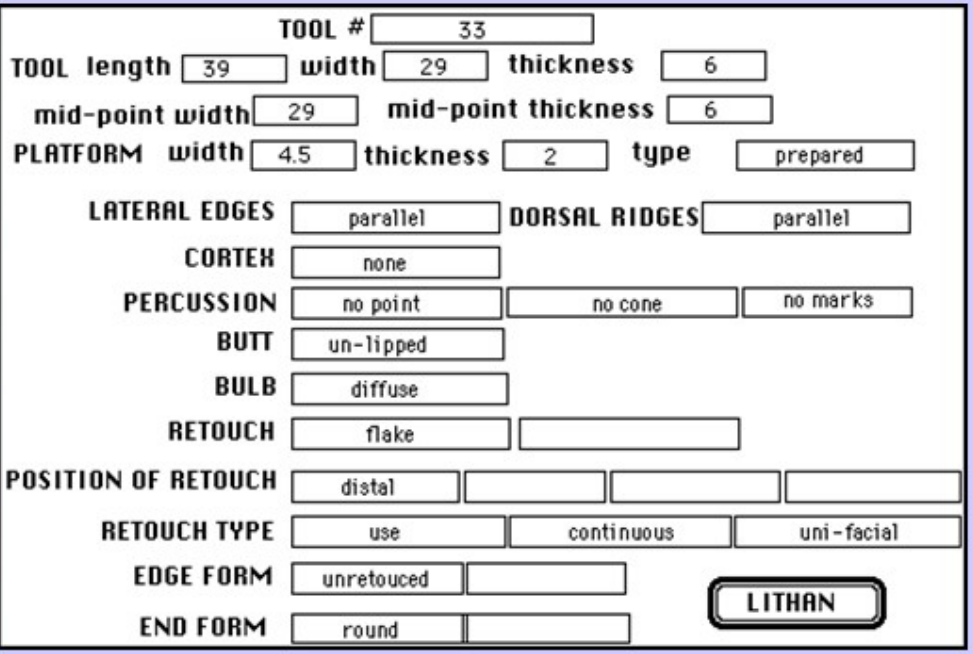
IF (x) is a settlement
And (x) has (y) in quantity (h)
And (y) is an object of ceramics
or (y) is a glassware
And (y) is dated in the 10 th century BC
THEN VERIFY THE ORIGIN OF (y)

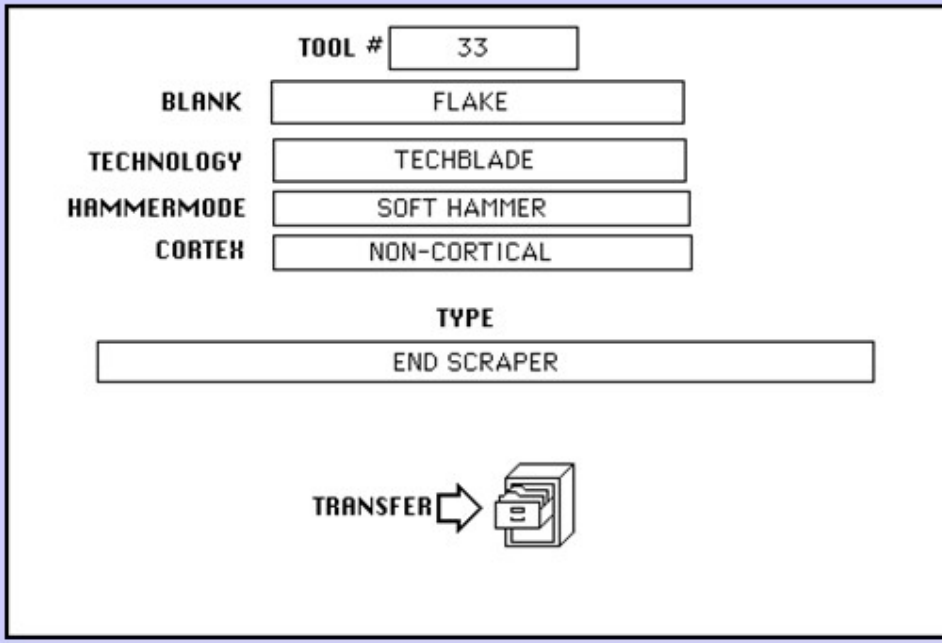
IF (Goal) is TO VERIFY THE ORIGIN OF (y)
And (y) is made of foreign material
THEN (y) is an Imported Object

IF (y) is an Imported Object
And (y) is similar to the Muslim pottery from the Castle of Silves (Portugal)
THEN (x) has Foreign Trade evidence.

LITHAN (LITHic ANalysis of stone tools)

http://www.hf.uio.no/iakk/roger/lithic/expsys.html.





LITHAN (LITHic ANalysis of stone tools)

http://www.hf.uio.no/iakk/roger/lithic/expsys.html.

```
If  length/width ratio >2
    and width <12 mm.
        then put "BLADE
         LET"
```

```
if      platform Thickness <5
    and     ButtType =
"prepared"
    and     Sides = "parallel"
    and     Ridges = "parallel"
then        put "TECHBLADE"
```

```
if      diff (length - width) > 0
        and distalRetouch =
"DISTAL"
then   put "END SCRAPER"
```

```
If      percussionCone = "no cone"
    and     butt = "un-lipped"
    and     bulb = "diffuse"
then        put "SOFT HAMMER"
```

```
if      endForm = "ROUND"
then        put "END SCRAPER"
```

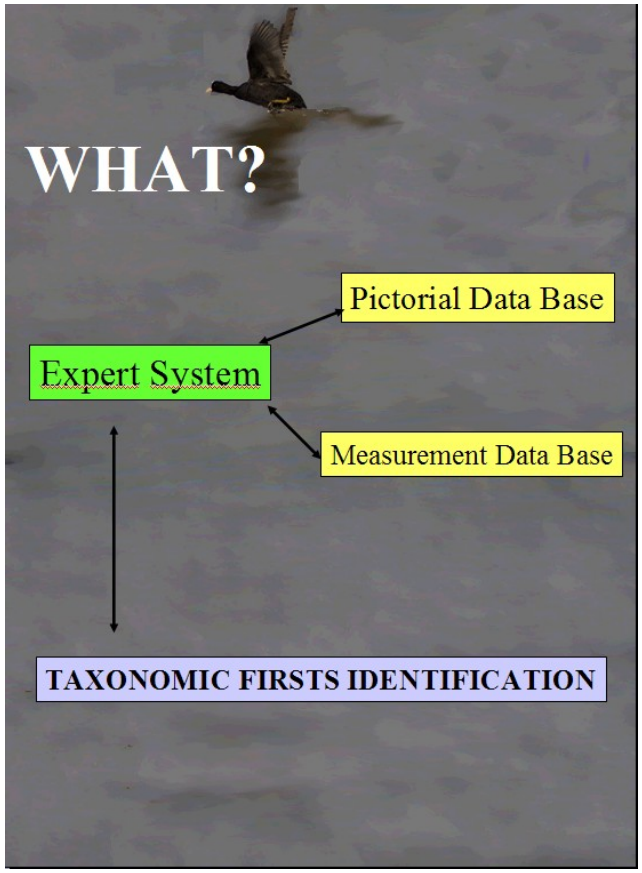
```
    if      endForm = "CARINATED"
    then put "CARINATED END SCRAPER"
```

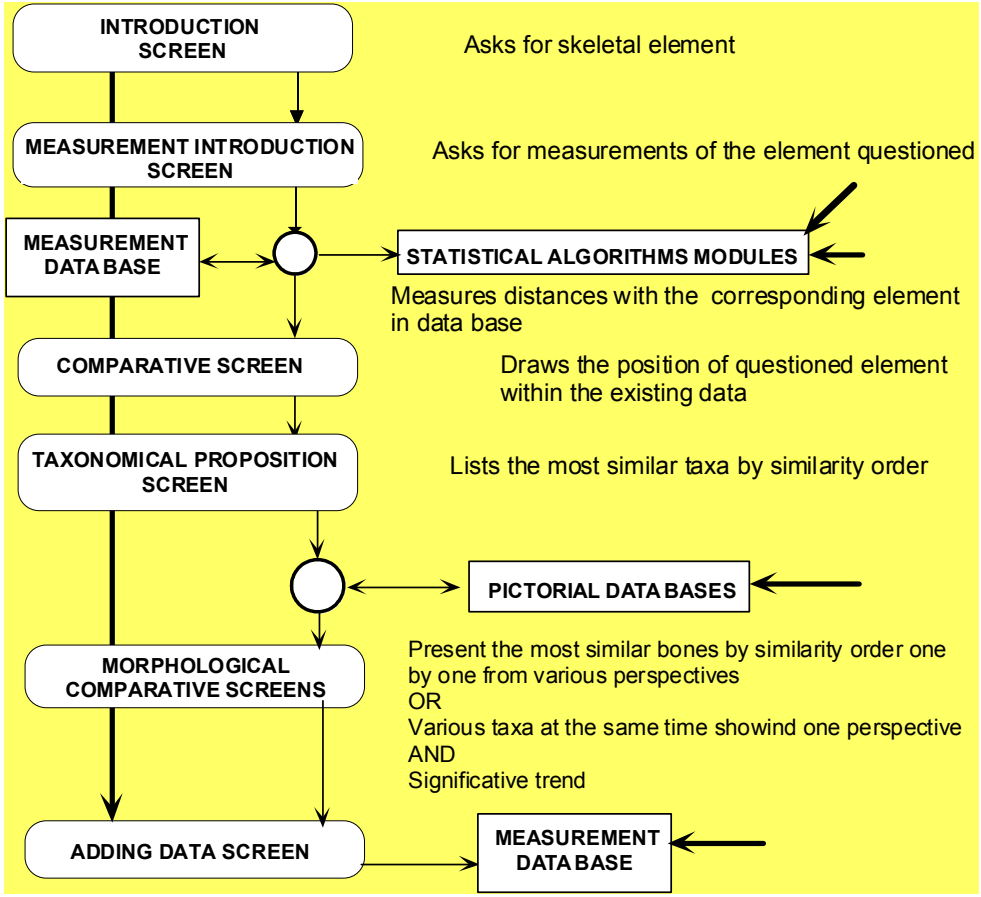
```
IF          "cutting" <4
      AND   "scraping" >8
      AND   "grooving" <2
      AND   "whittling" <2
THEN        PUT "SCRAPING"

IF          "soft" >4 and <8
      AND   "medium" >0 and <2
      AND   "hard" = 0
THEN        PUT "SOFT"

IF          "soft" <6
      AND   "medium" >5
      AND   "hard" <4
THEN        PUT "WOOD"
```

```
IF          "soft" >2 and <6
      AND   "medium" <8
      AND   "hard" <2
      AND   MOTION "whittling" OR "boring/drilling" OR "grooving" OR
            "chopping/adzing"
THEN PUT "HIDE"
```

```
IF          "soft" =0,
      AND   "medium" >3,
      AND   "hard" >8,
      AND   MOTION "whittling" OR "cutting" OR "piercing" OR "chopping/adzing"
            OR "grooving",
      AND   SUBTYPE "facet" (when referring to a burin),
THEN        PUT "STONE".
```

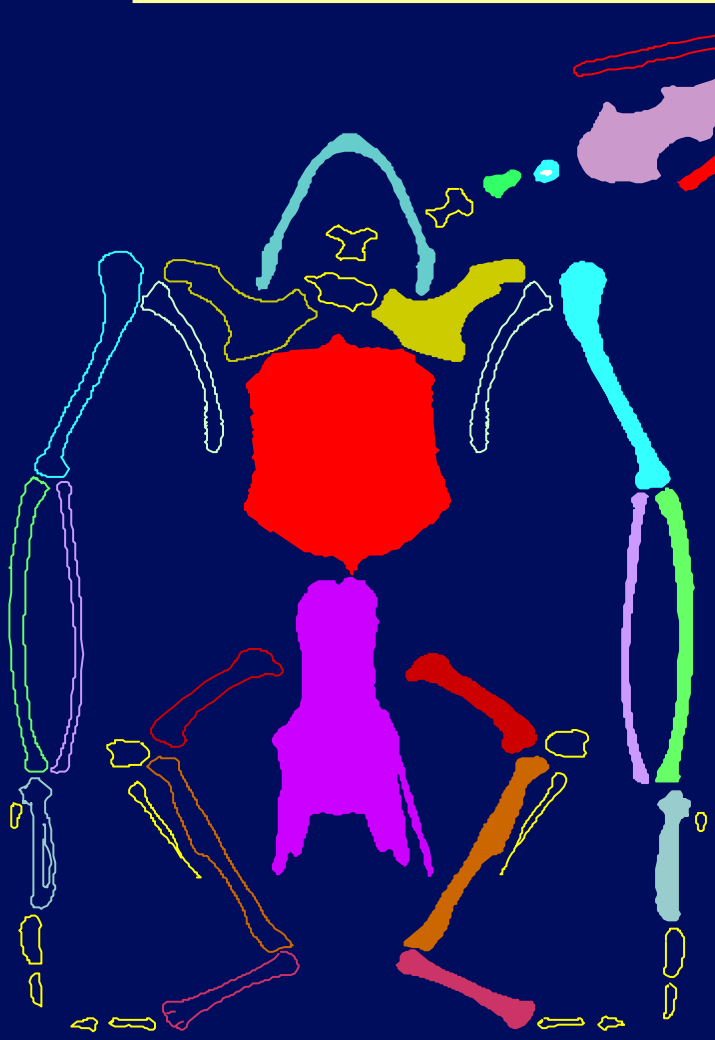
AVIAN ARCHAEOZOOLOGY





INTRODUCTION SCREEN

Please Choose Skeletal Element



CRANIUM

MANDIBULA

ATLAS

AXIS

FURCULA

CORACOIDES

SCAPULA

HUMERUS

ULNA

RADIUS

CARPOMETACARPUS

STERNUM

PELVIS

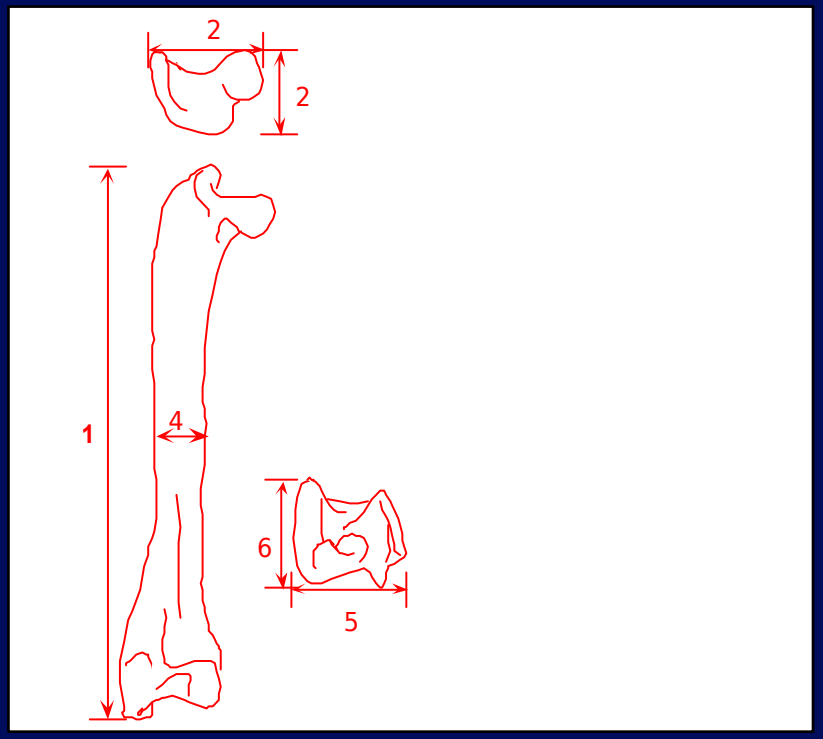
FEMUR

TIBIA

TARSOMETATARSUS

MEASUREMENT INTRODUCTION SCREEN

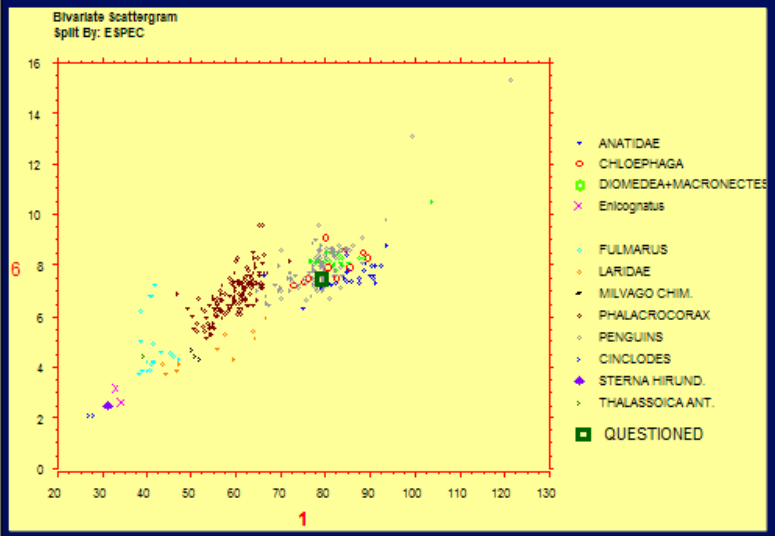
Please Introduce measurements
Following the scheme



1.-	77.2
2.-	16,8
3.-	12,1
4.-	7,8
5.-	14,9
6.-	14,4

COMPARATIVE SCREEN

BIVARIATE SCATTERGRAM

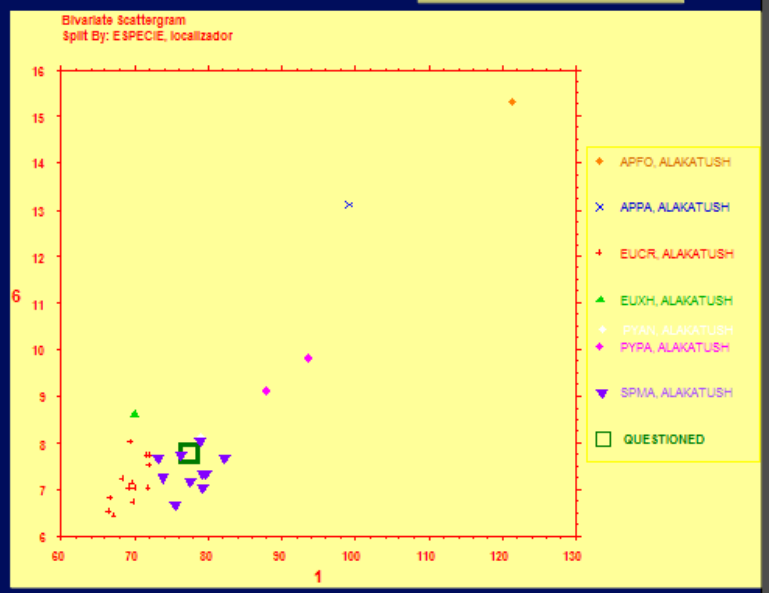


ZOOM

END

COMPARATIVE SCREEN

BIVARIATE SCATTERGRAM

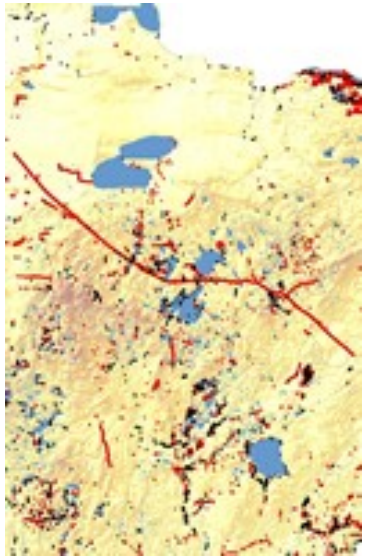


LOG RATIO

END

Mn/Model
Minnesota Statewide Archaeological Predictive Model

Model is the first archaeological predictive model to make survey bias explicit in the final results so that the model's value for any given place can be assessed.
As we evaluated the Site Probability Models, it became apparent that they predicted surveyed places almost as well as they predicted site locations. This implied a high degree of survey bias and reduced our confidence in the interpretation of the predictive models, posing the question of whether areas were categorized as low probabity because no sites were there or because there had been no surveys there. This led to the development of the Survey Probability Model, which might be thought of as a model of survey bias

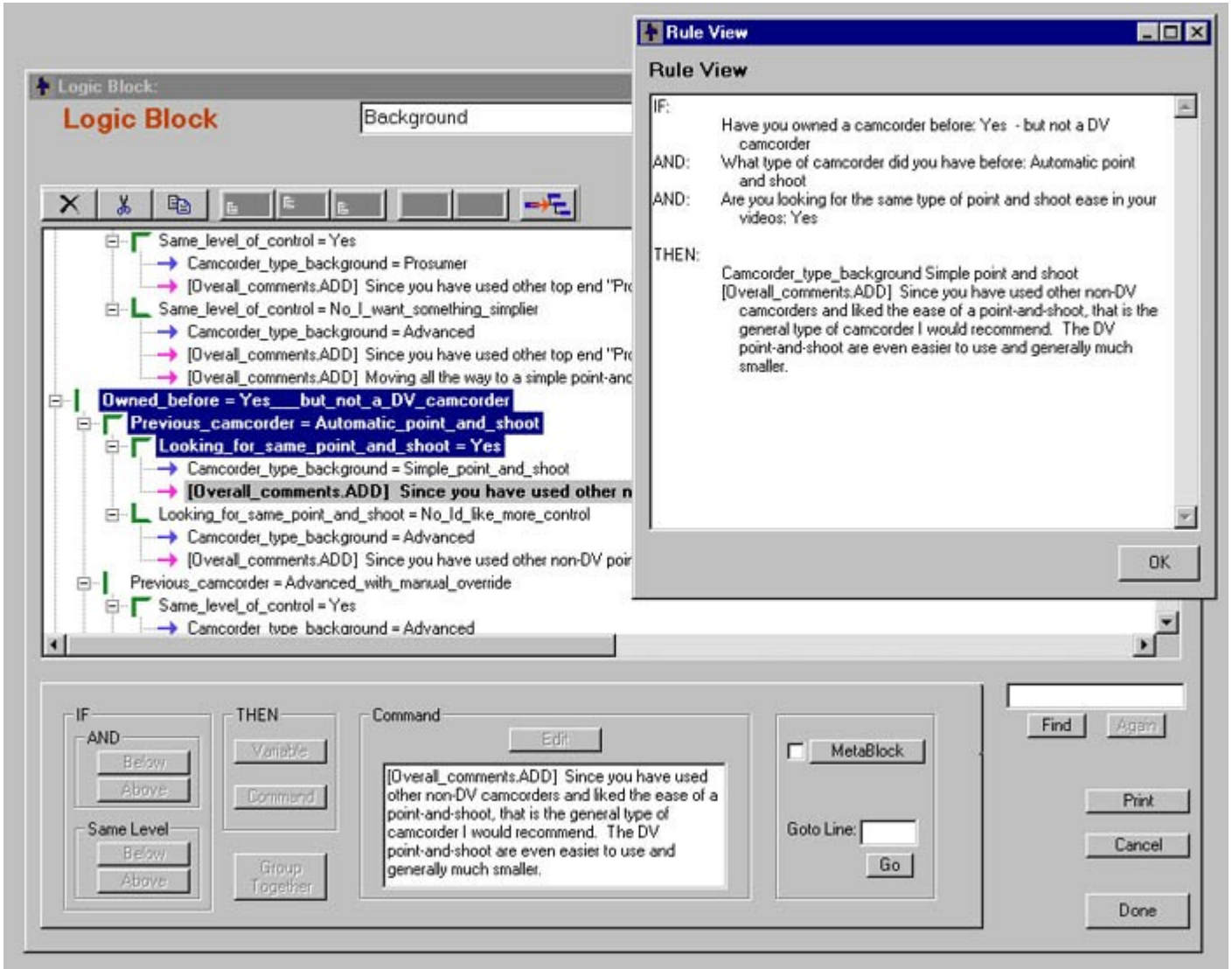


http://clipsrules.sourceforge.net/

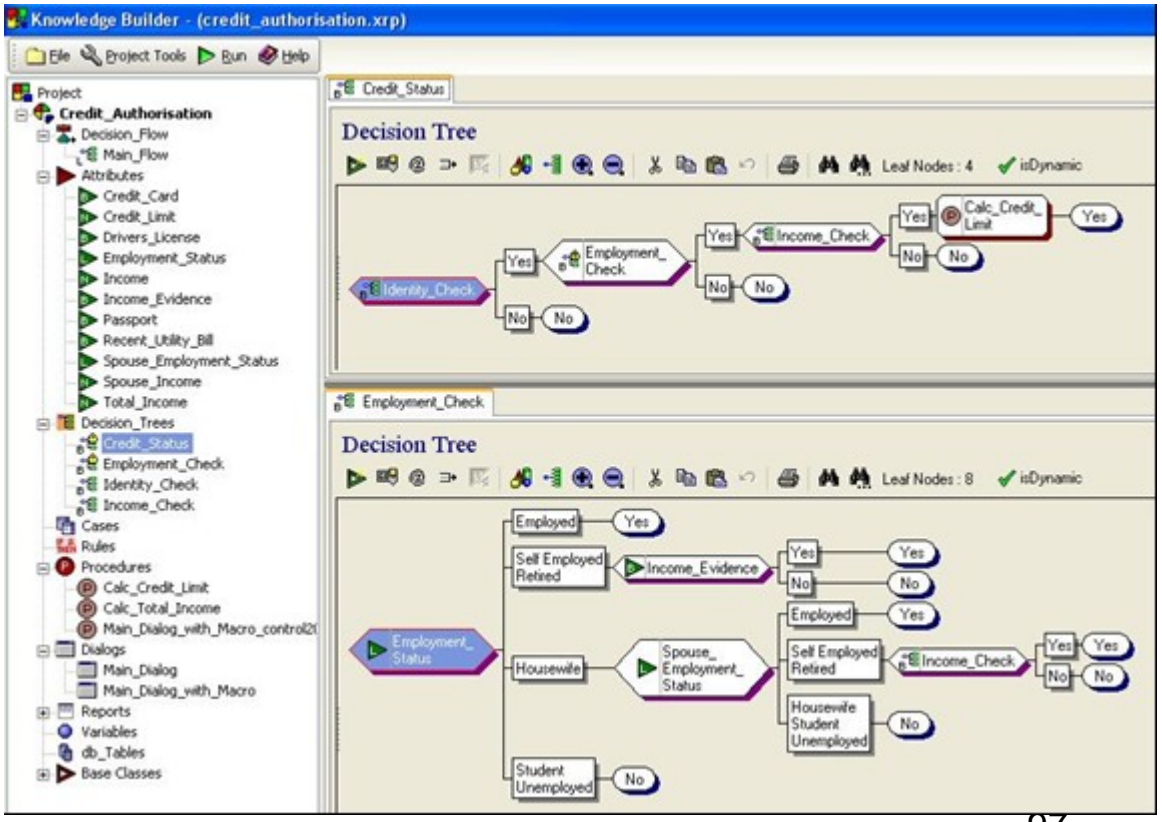
http://www.jessrules.com/

http://protege.stanford.edu/

http://www.exsys.com/exsyscorvid.html



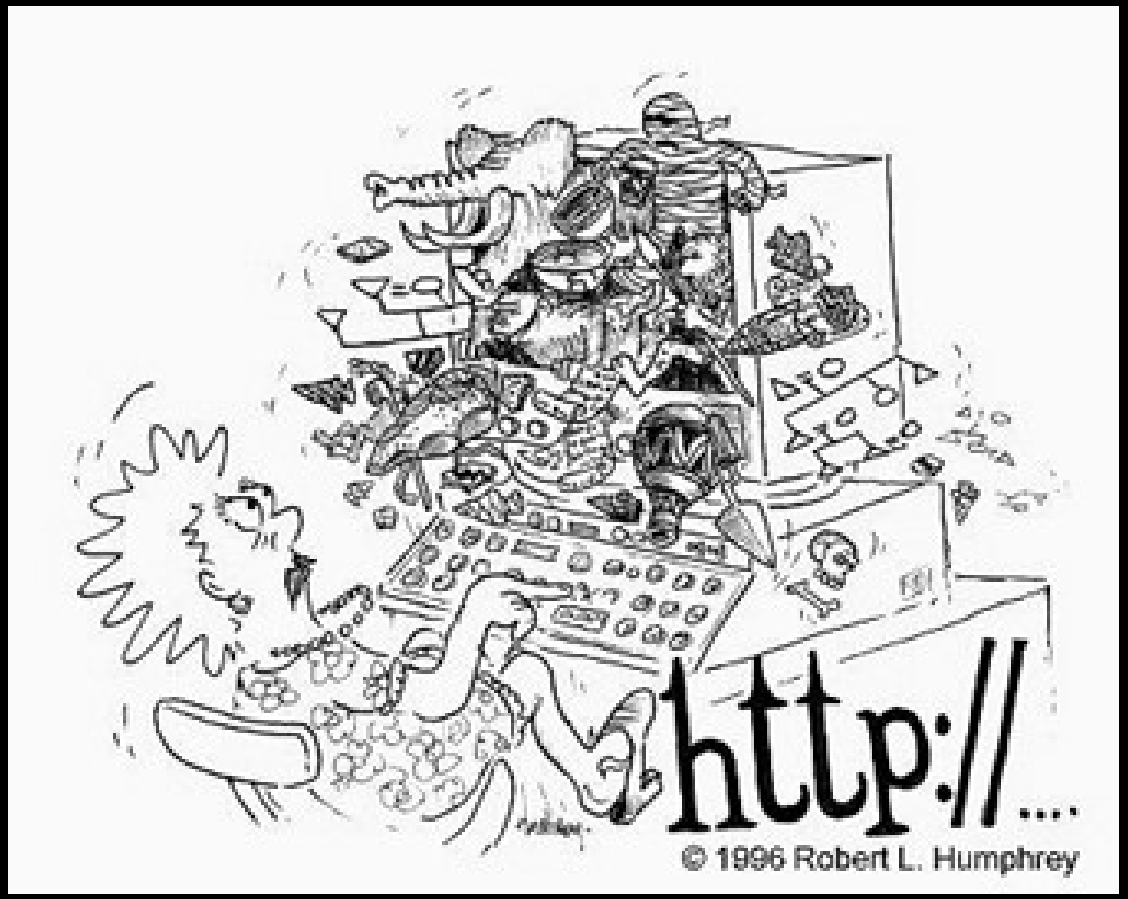
http://www.xpertrule.com/pages/authoring-studio.htm



1985

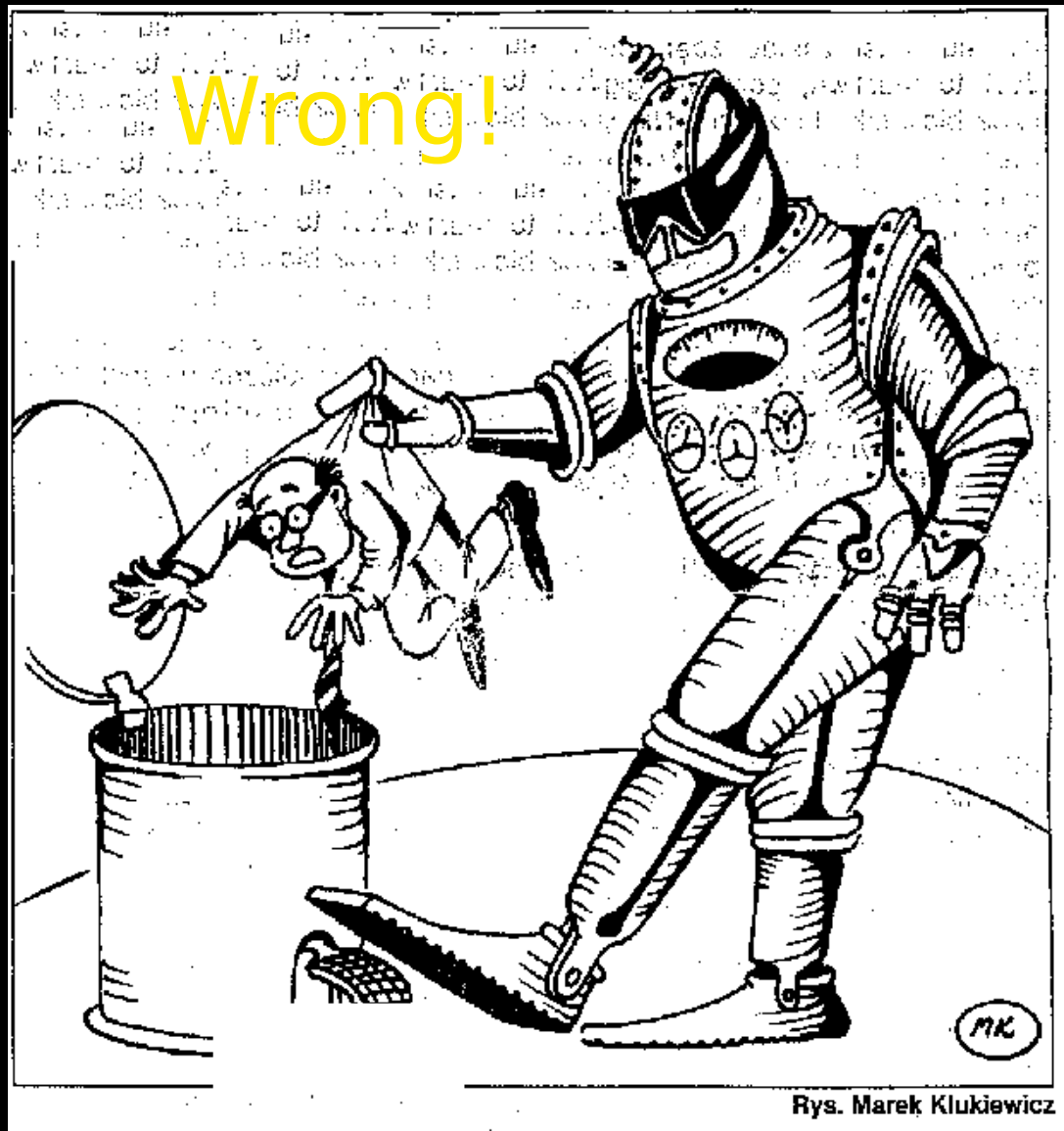
Are Machines capable of doing any work a man can do?

As suggested by H.Simon In 1965

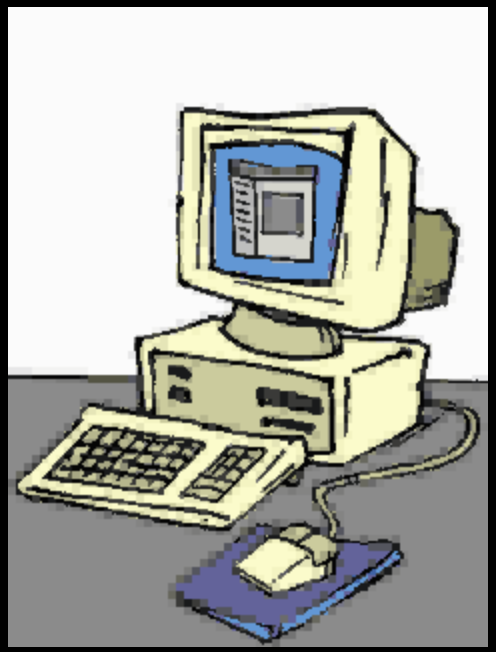


“Machines will be capable of doing any work a man can do by 1985”.

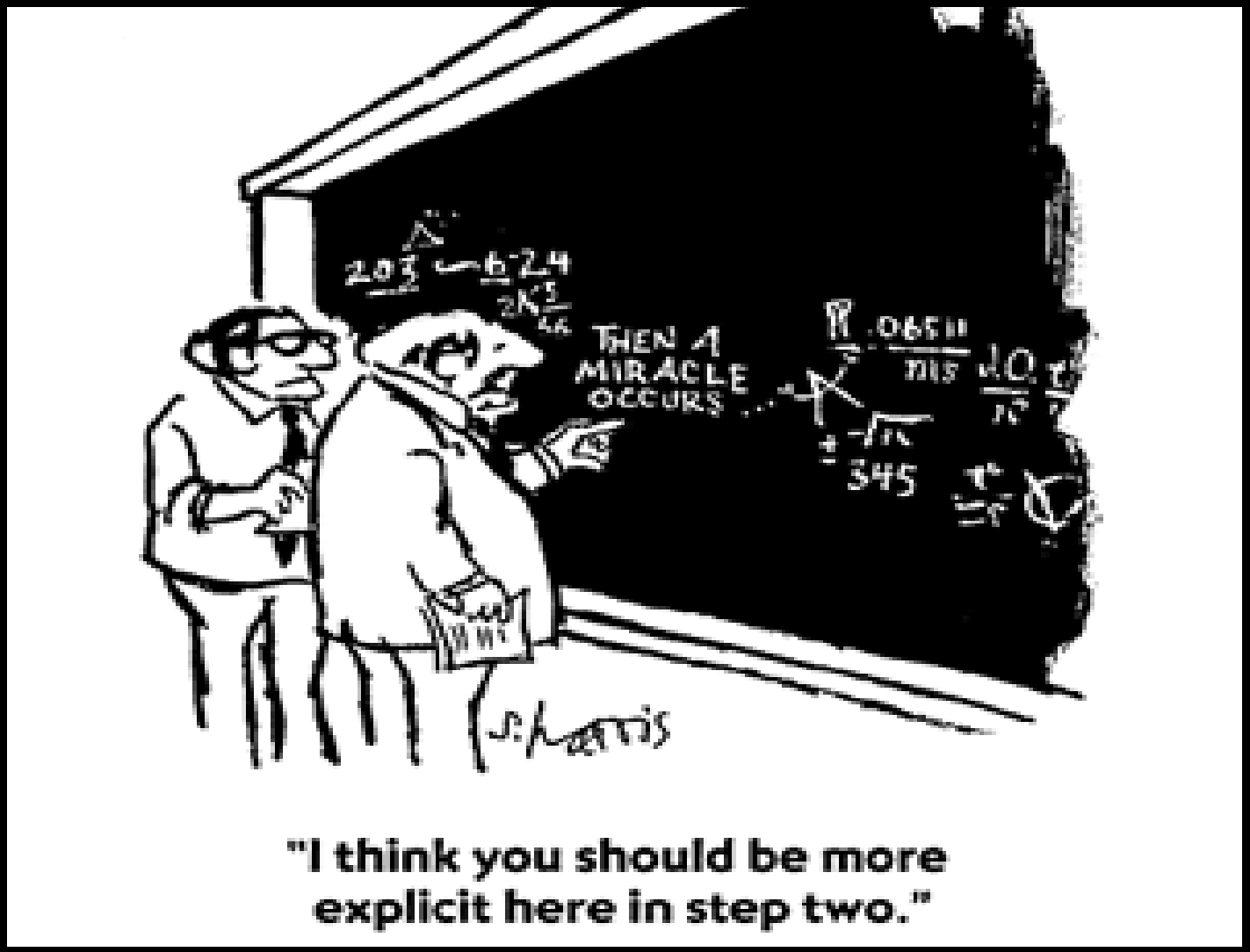
Herbert Simon, in 1965



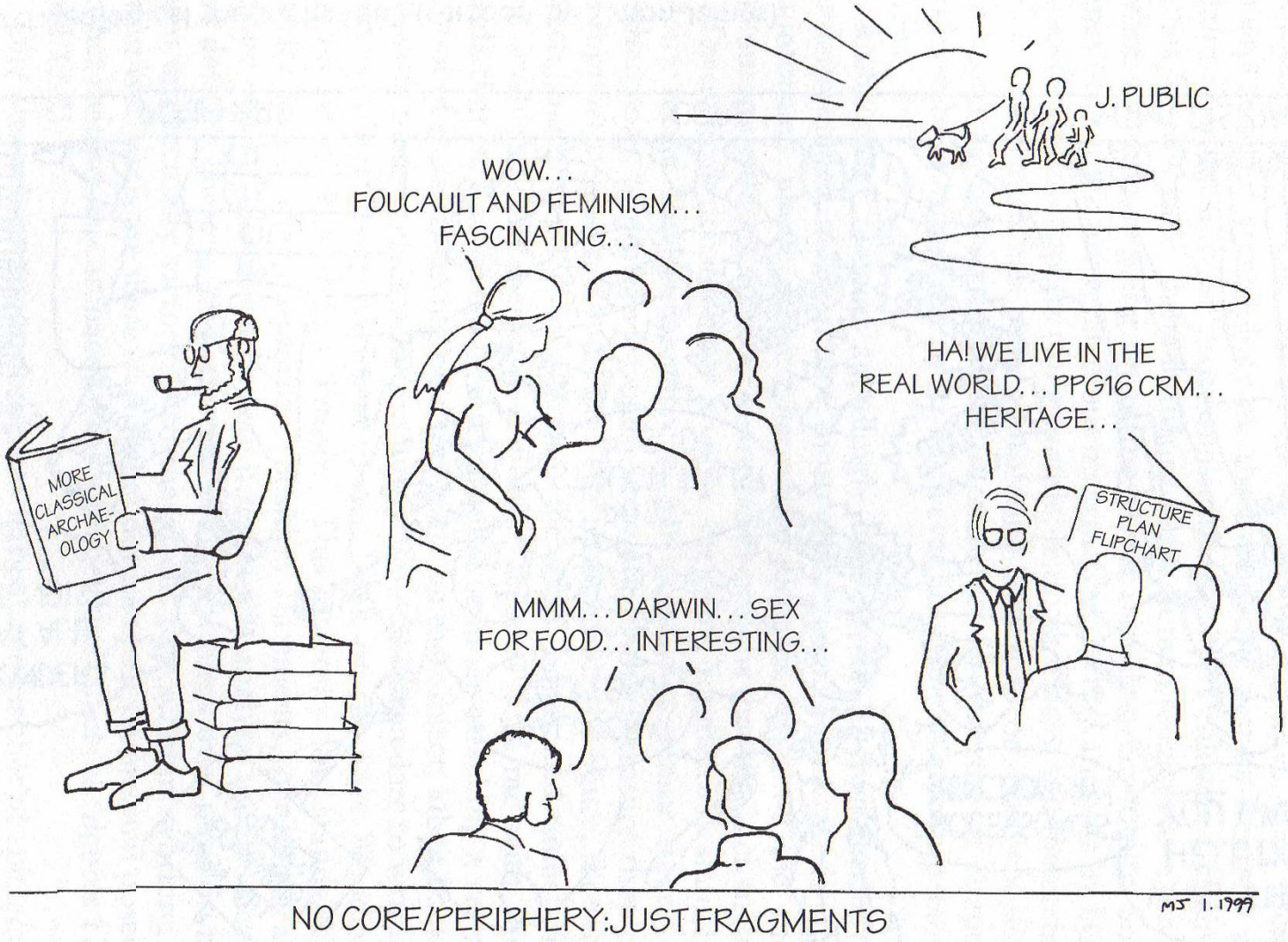
1985: Computational Intelligence: the end of a myth?



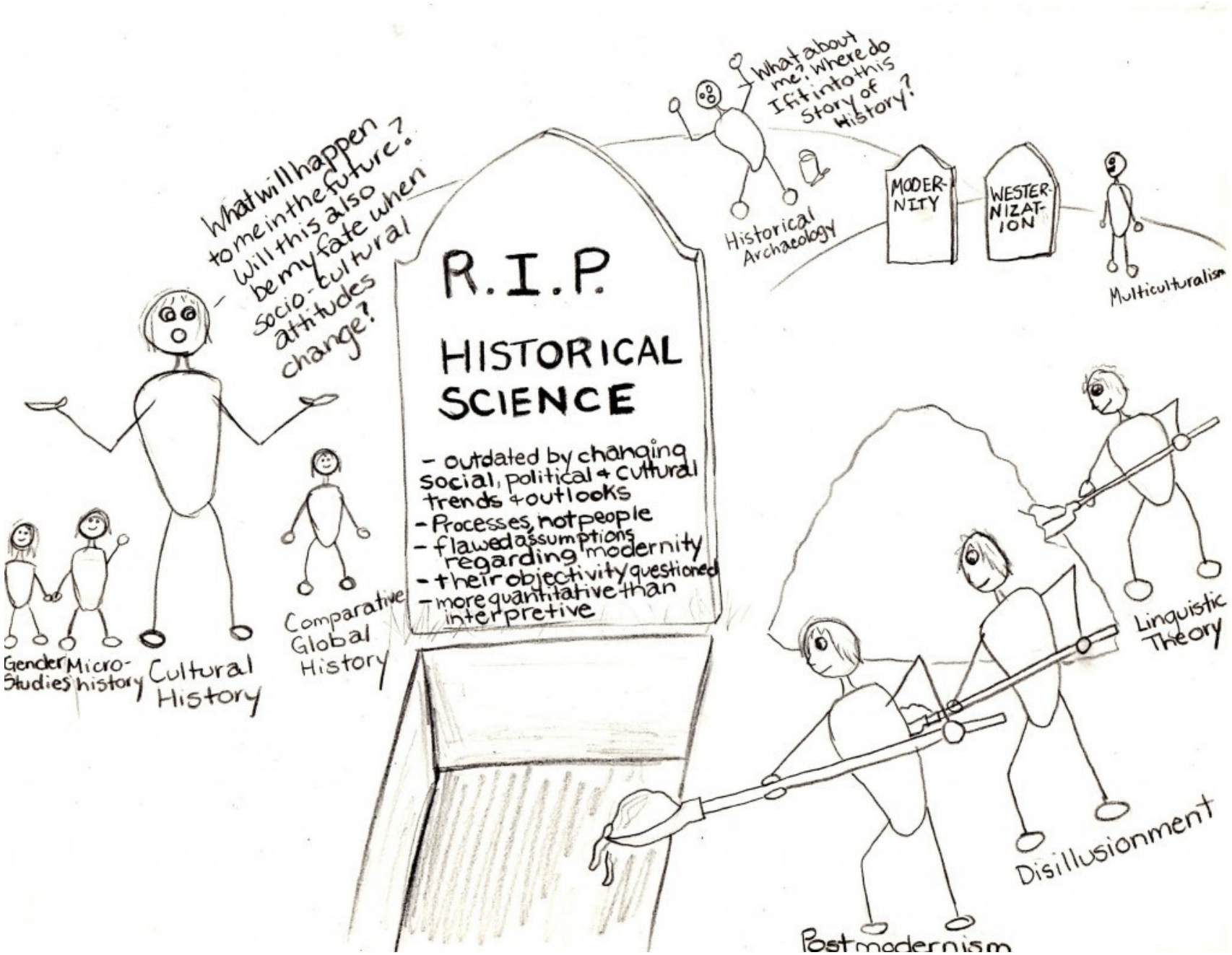
1985: Explicitly Scientific Archaeology: the end of a myth?



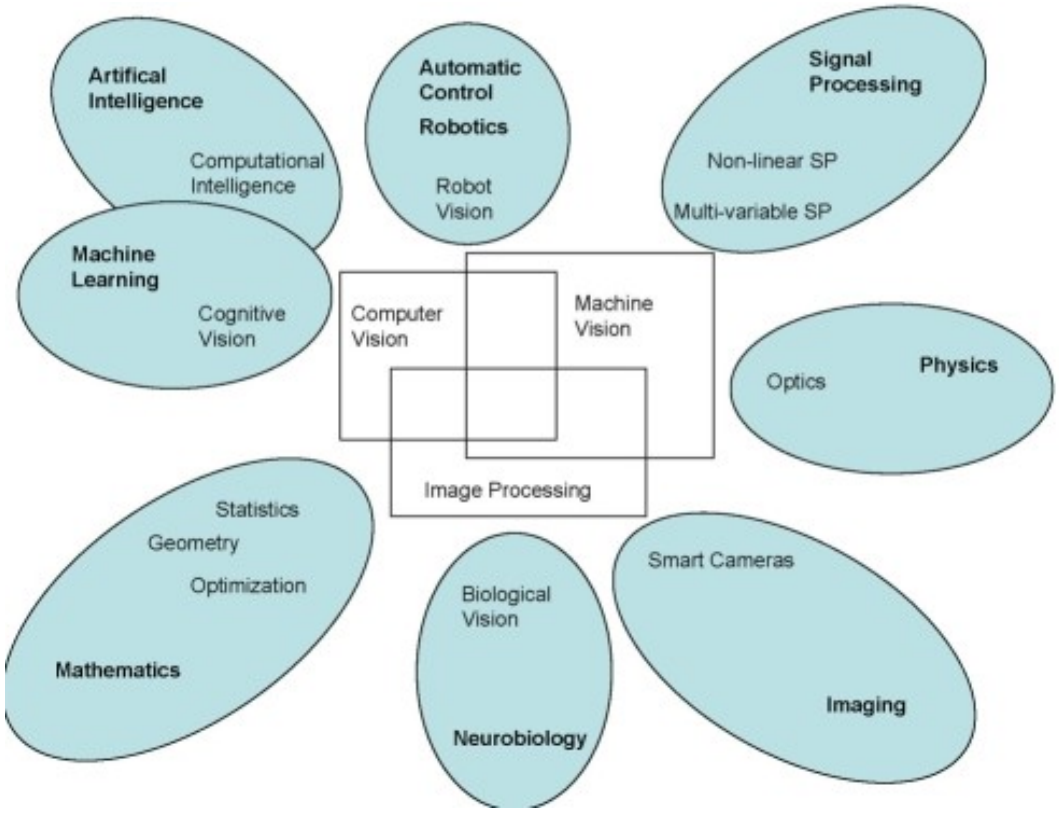
"I think you should be more explicit here in step two."



Archaeological theory in 1998 (cartoon by Matthew Johnson).


What will happen to me in the future? Will this also be my fate when socio-cultural attitudes change?
R.I.P.
HISTORICAL SCIENCE
- outdated by changing social, political & cultural trends & outlooks
- Processes, not people
- flawed assumptions regarding modernity
- their objectivity questioned
- more quantitative than interpretive
What about me, where do I fit into this Story of History?
Historical Archaeology
MODERNITY
WESTERNIZATION
Multiculturalism
Gender Studies
Micro-history
Cultural History
Comparative Global History
Linguistic Theory
Disillusionment
Postmodernism

“New” Artificial Intelligence (1985….)

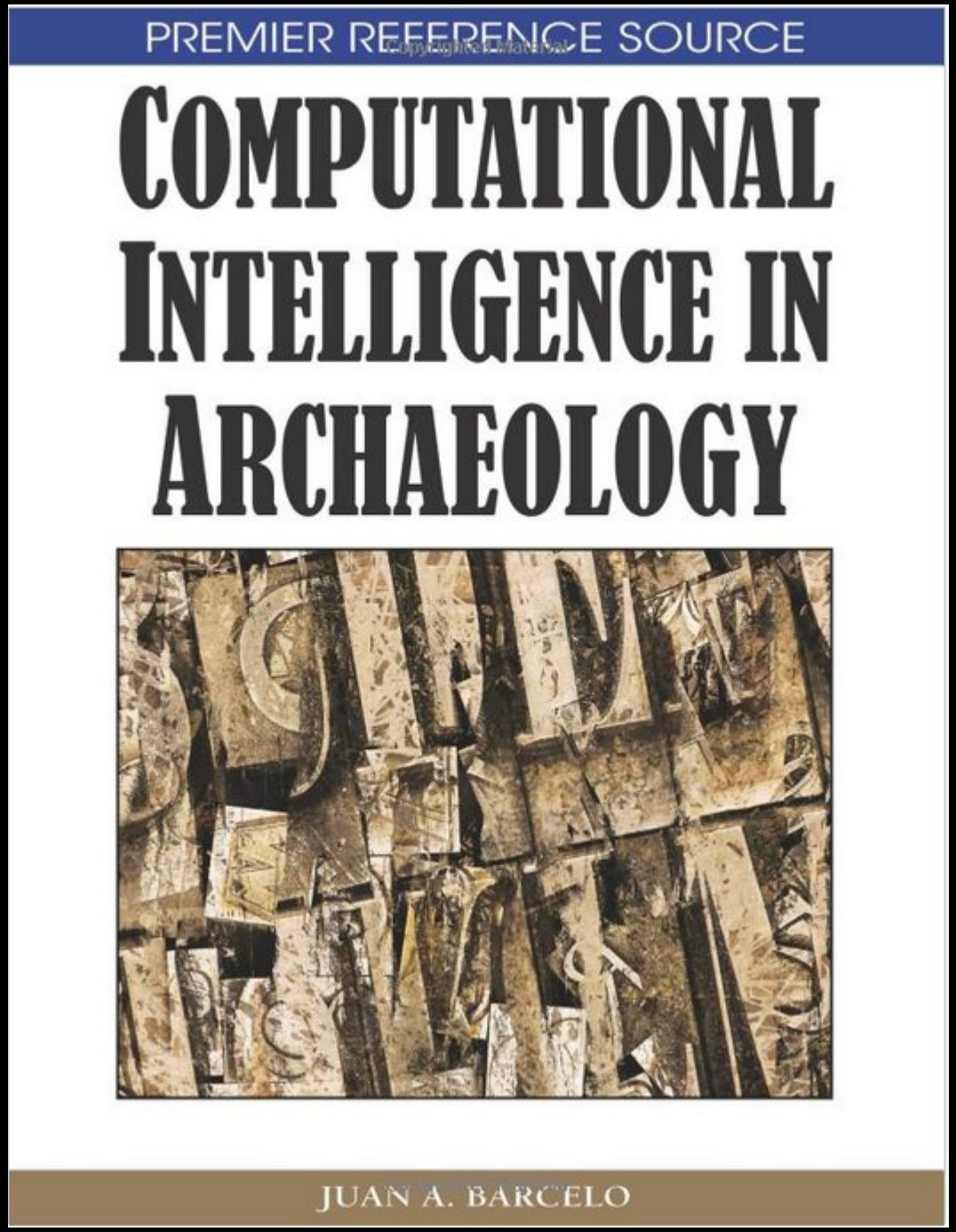



A.I. of the PAST...
INVALID INPUT.
DATA OVER-LOAD!
BZZZ.
ANALYSIS ERROR 401...
A.I. of TOMORROW...
MY REPORT IS ON YOUR DESK, YOUR SHOELACE IS UNTIED AND TOMORROW IS YOUR WEDDING ANNIVERSARY.

A reference Book:

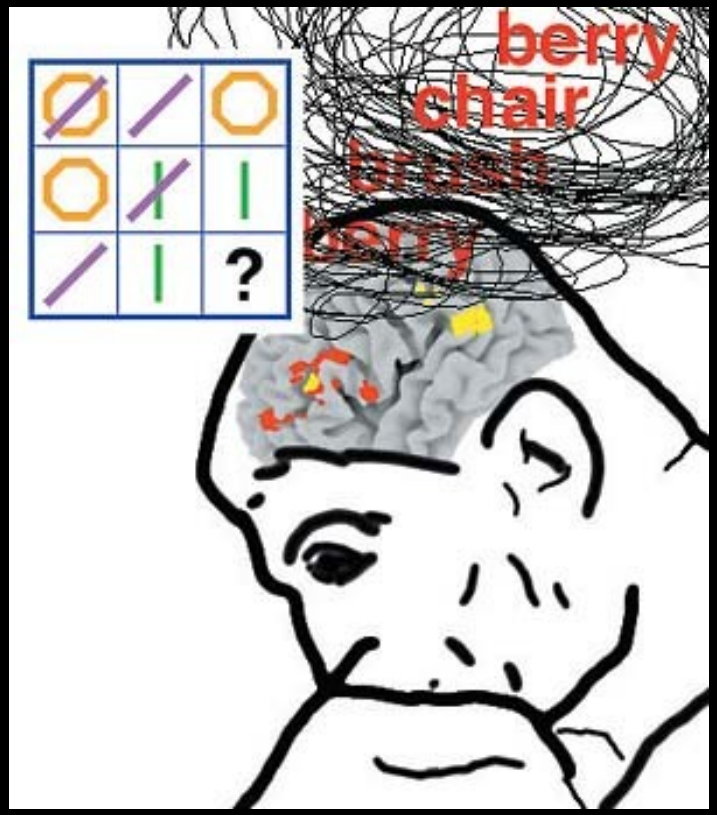
COMPUTATIONAL INTELLIGENCE IN ARCHAEOLOGY.

Investigations at the Interface between Theory and Technique in Anthropology, History and the Geo Sciences



Problem Solving

A person has a "problem" when she or he has a goal which cannot be achieved directly. Whenever one cannot go from the given situation to the desired situation simply by action, then there is recourse to thinking.



It is mainstream archaeology, and not the “possibility” of intelligent computer programs, what appears to be “narrow minded

We want to see what cannot be seen

This is an INVERSE PROBLEM:
Given the actual evidence of the effect, we should be able to *predict* the past existence of the cause

An archaeological site is the PLACE where social action was once performed…

but we have no direct perception about **what** happened there nor **why**

An archaeological site is the PLACE where social action was once performed

Archaeological problems

The material consequences of human Behavior(labour) → **What is this?**

↓

What kind of activity, in the past, caused, determined, constrained what I see *in the present (arch. record)* → **Why this is so?**

↓

What kind of activity, in the past, caused, determined, constrained the action having generated the Archaeological record → **Why this happened there and then?**

The Structure of Archaeological Intelligence

DATA

?

→ EXPLANATIONS

Problem Solving in Archaeology

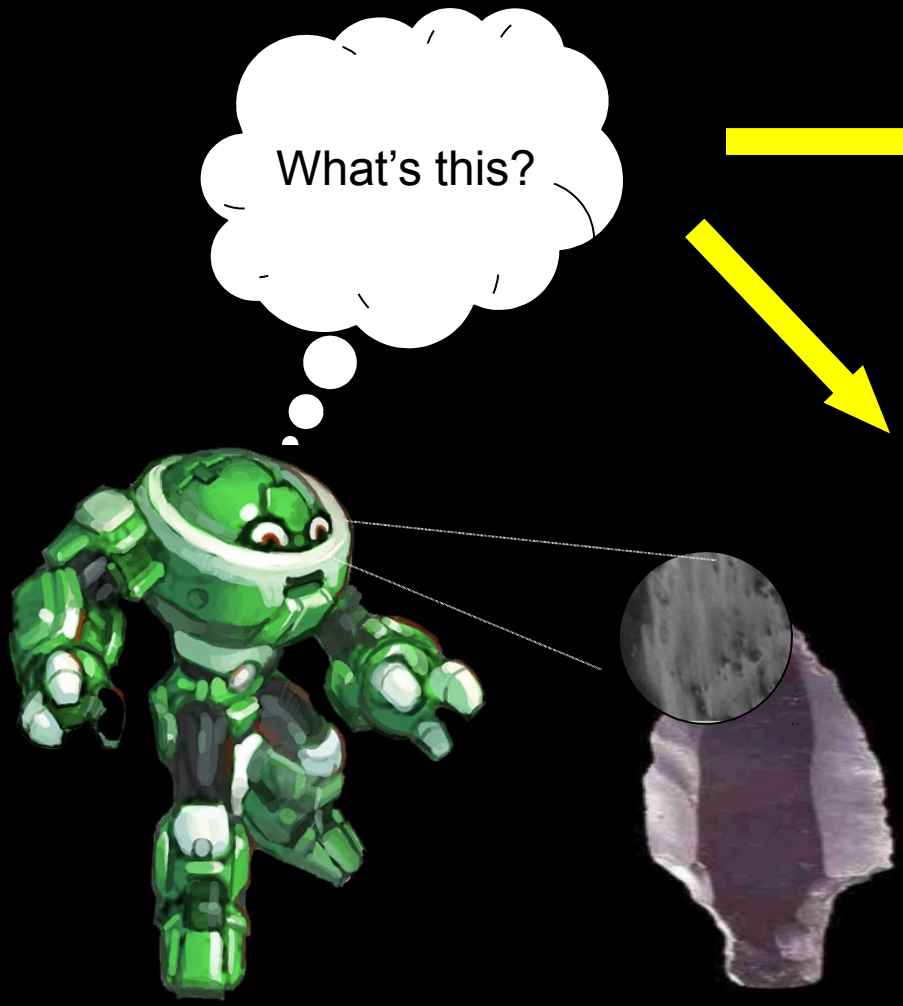
Social Action ⟶ **Archaeological Record**

PRODUCTION
DISTRIBUTION
USE

Physical Properties
Shape
Size
Composition
Texture

Locational Properties
Space
Time

Causes *Effects*



Was it used as a bottle?

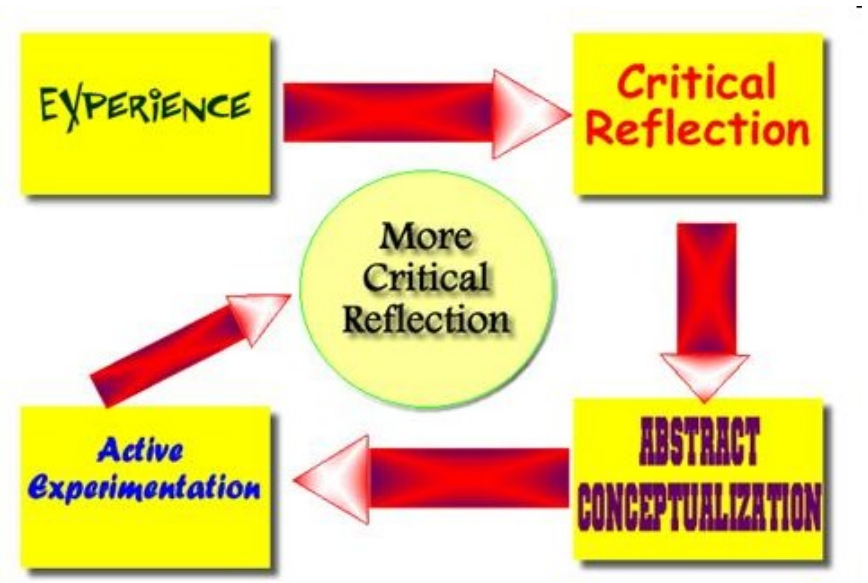
Was it used as an arrow point?

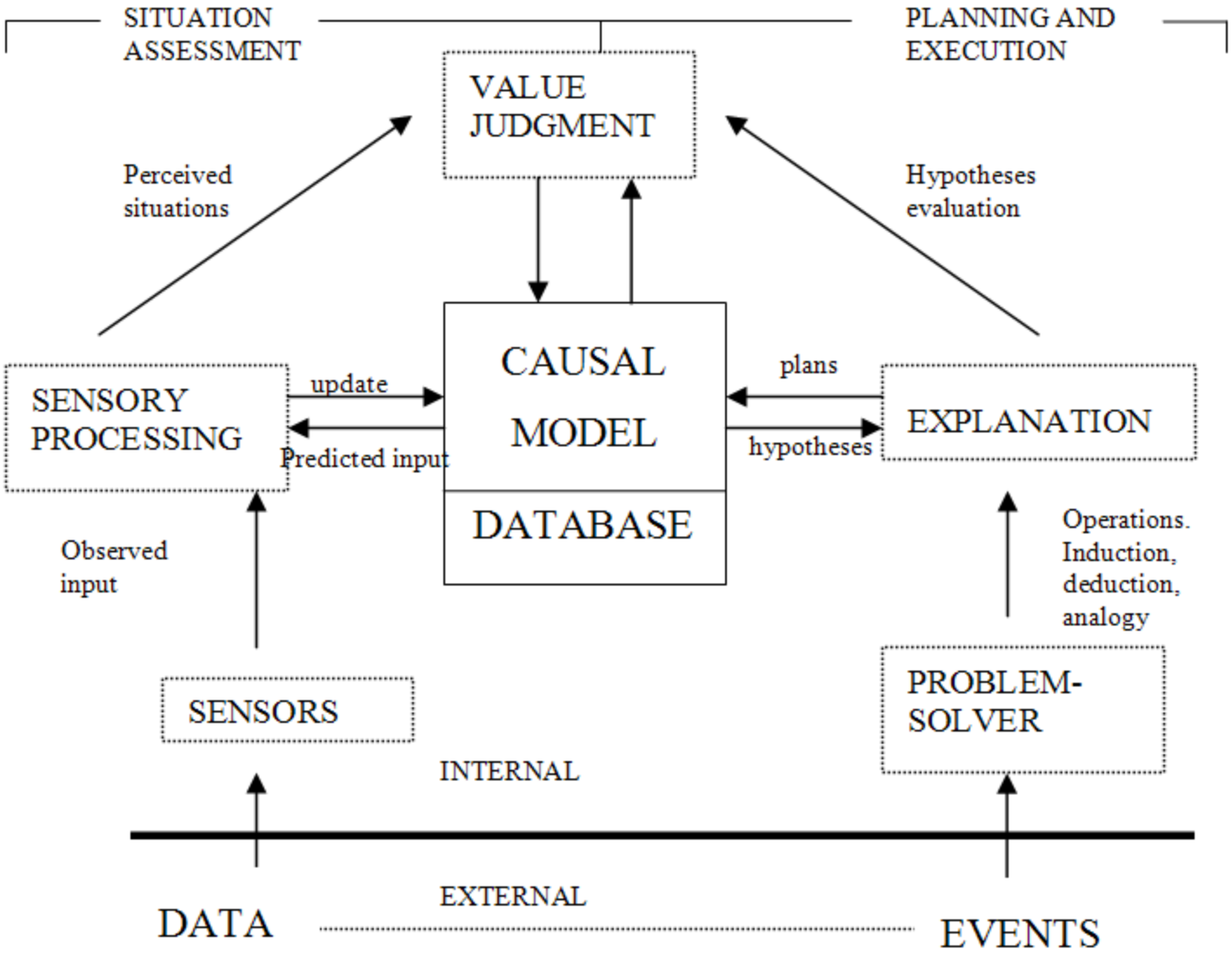
YES

What does it mean, to THINK?

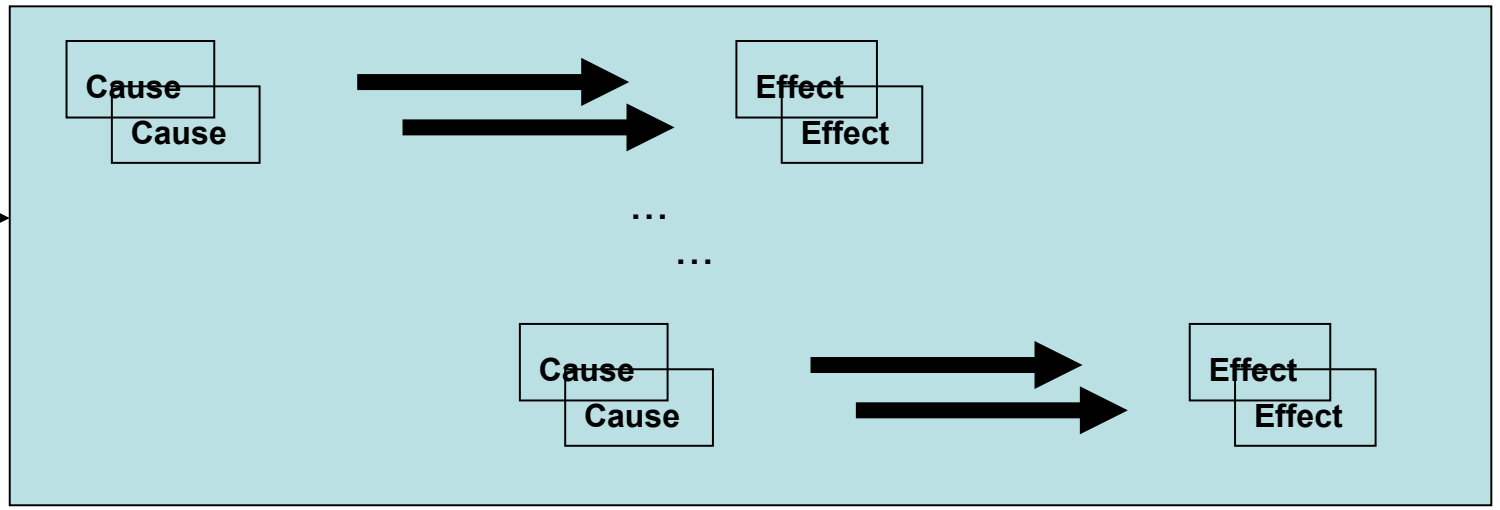
It is not "using knowledge", but *learning*

The task of concept learning is to acquire general concepts from specific training examples. Training examples are instances, which either belong to a special concept, and therefore are positive examples, or do not belong to the concept, and therefore are negative examples.




SITUATION ASSESSMENT
PLANNING AND EXECUTION
VALUE JUDGMENT
Perceived situations
Hypotheses evaluation
CAUSAL MODEL
DATABASE
SENSORY PROCESSING
update
Predicted input
plans
hypotheses
EXPLANATION
Observed input
Operations. Induction, deduction, analogy
SENSORS
PROBLEM-SOLVER
INTERNAL
EXTERNAL
DATA
EVENTS

OBSERVATION OF INDIVIDUAL INSTANCES



COMMUNALITIES

+

PRIOR KNOWLEDGE:

constraints that will ensure that the predictions drawn by an automated archaeologist will tend to be plausible and relevant to the system's goals

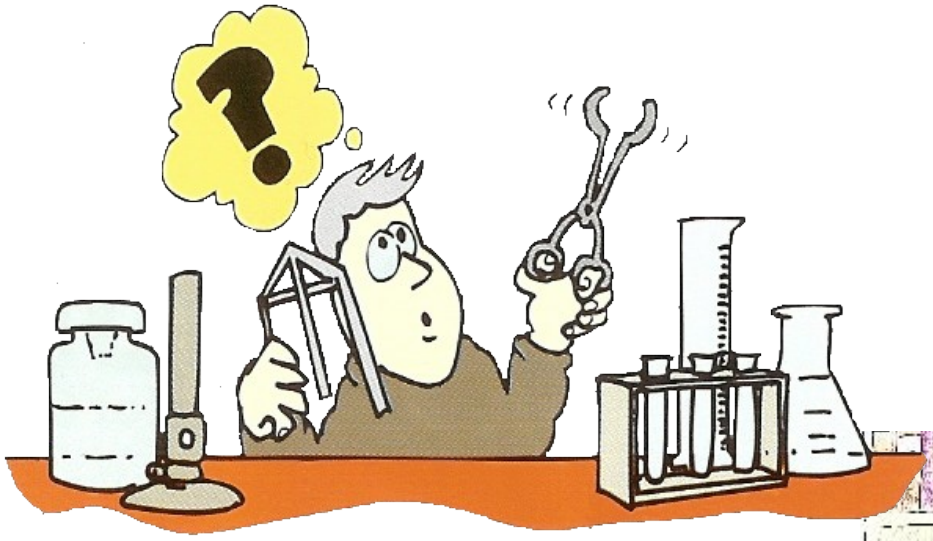
testing

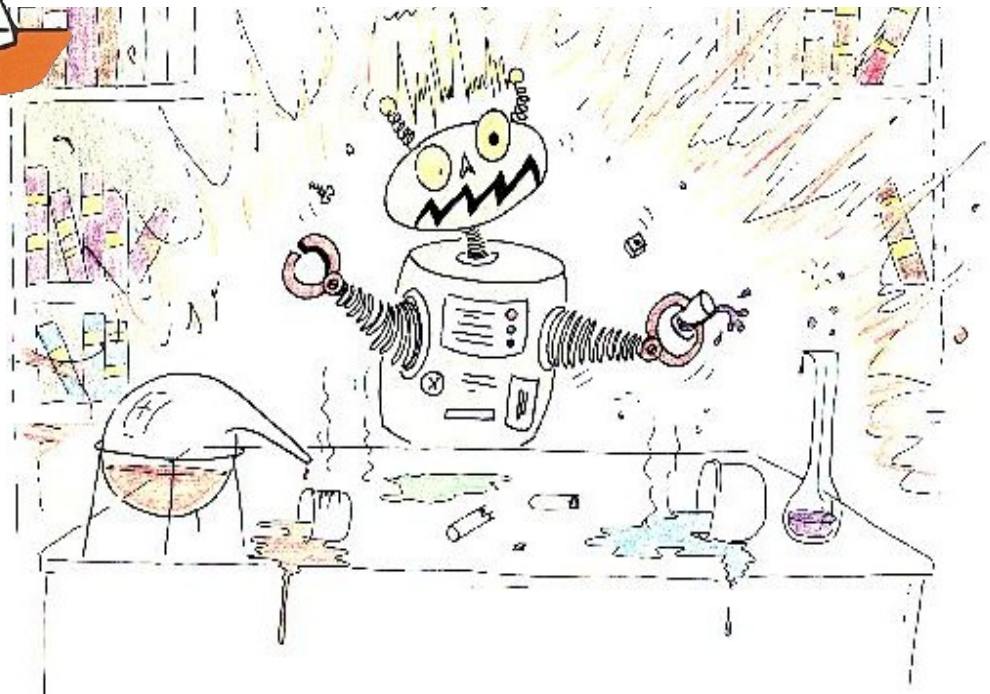
Feedback cycle

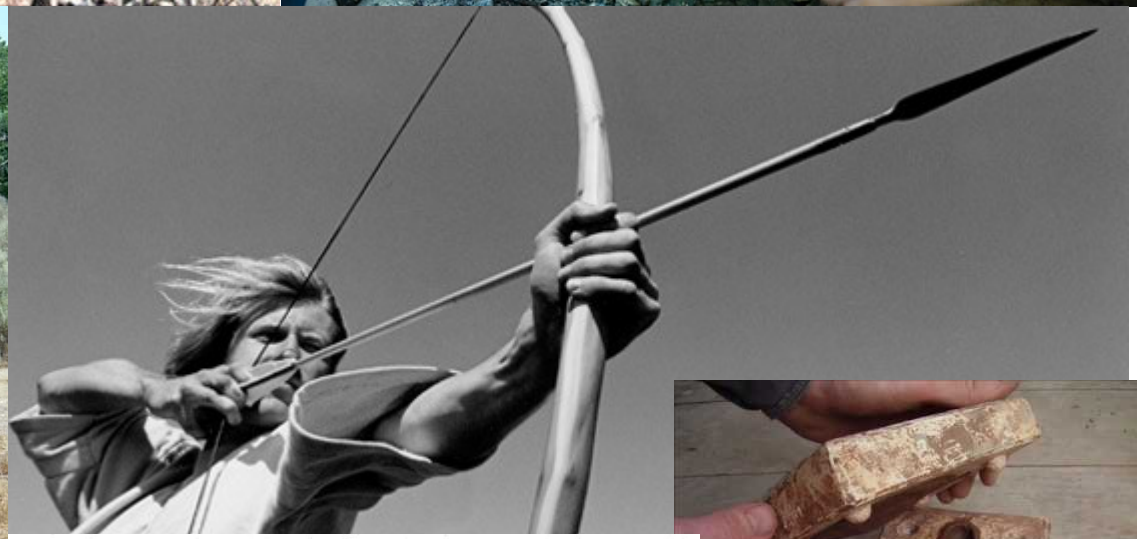
Cause → **Effect**

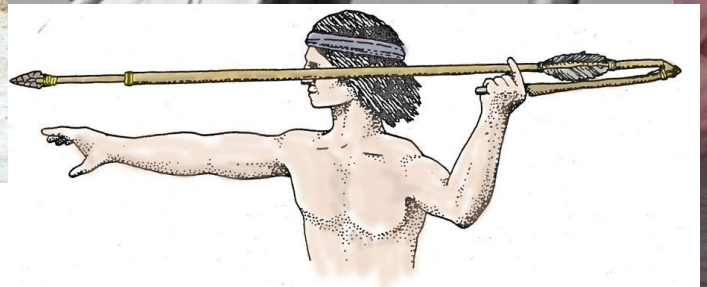
Inference of a general model

EXPERIMENTAL DESIGN

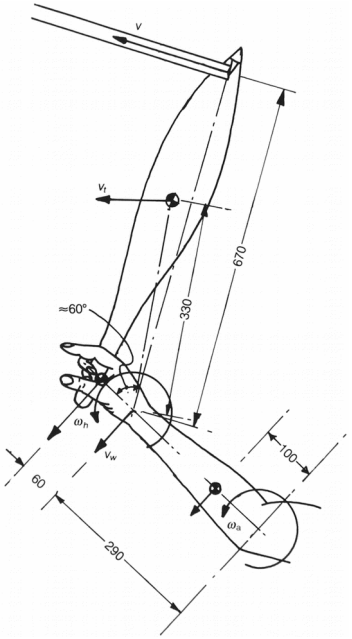


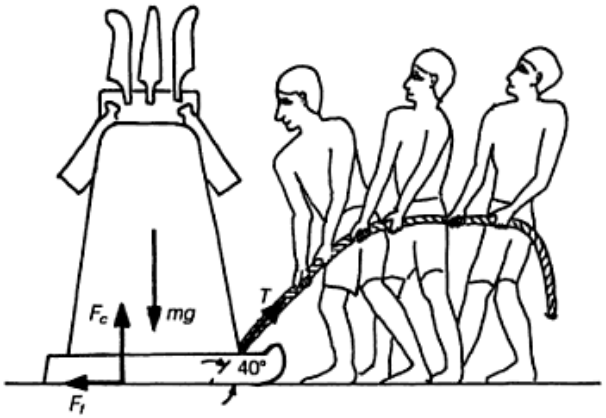


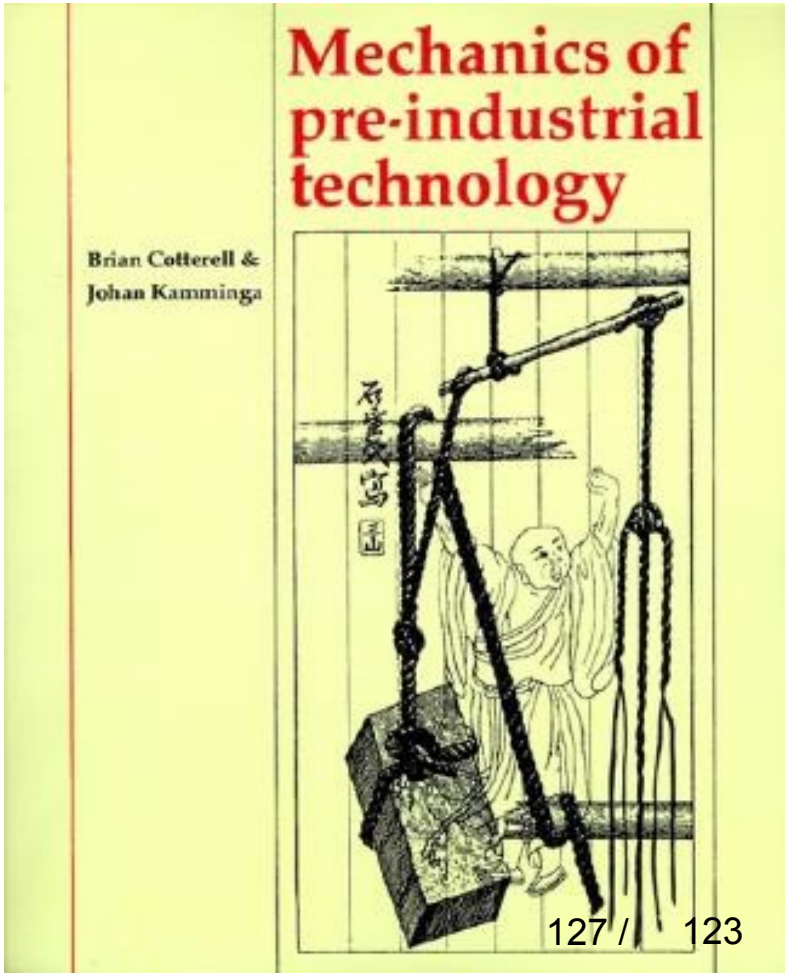




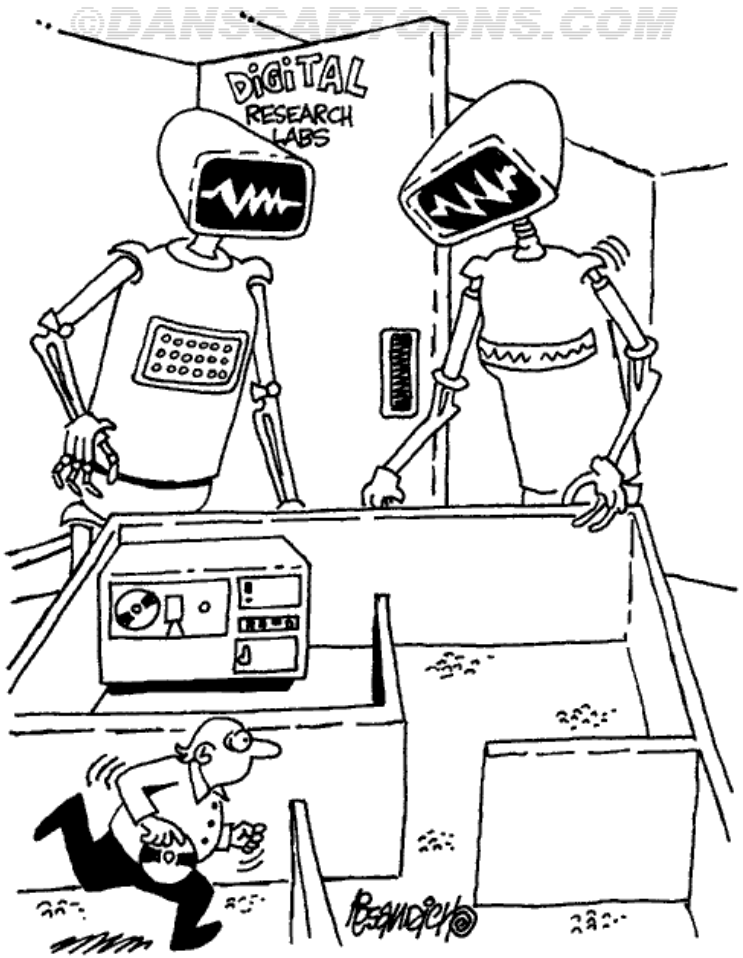
FUNCTIONAL ANALYSIS.







CONTROLED OBSERVATION= ETHNOARCHAEOLOGY



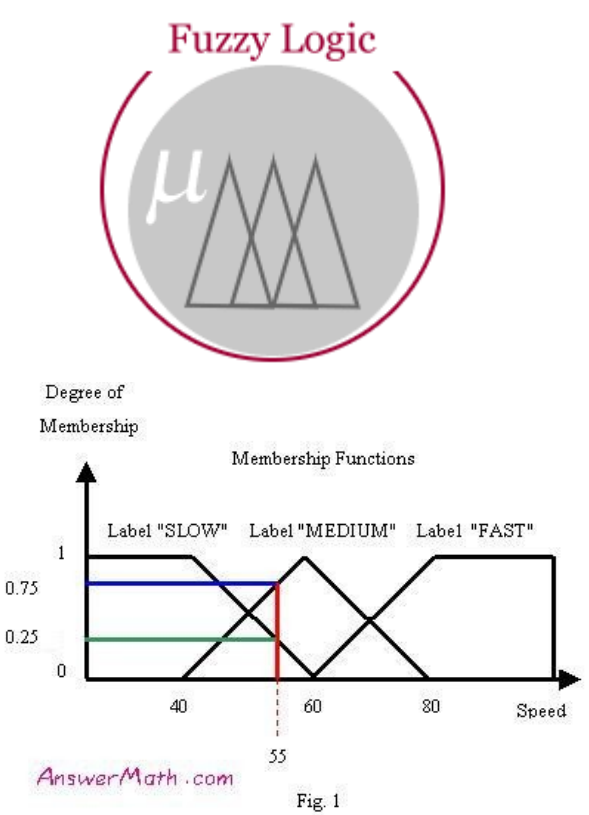
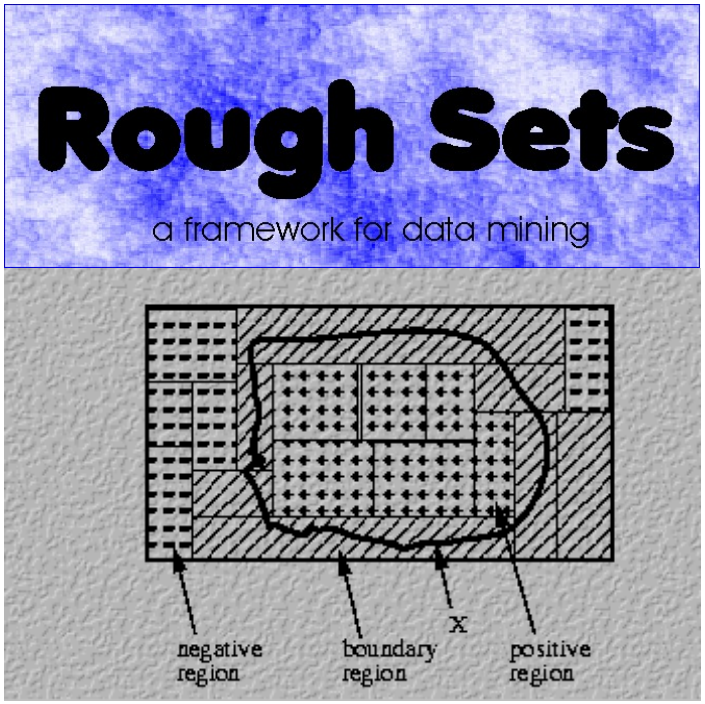
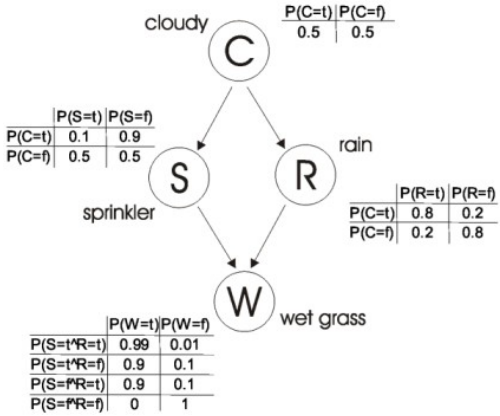
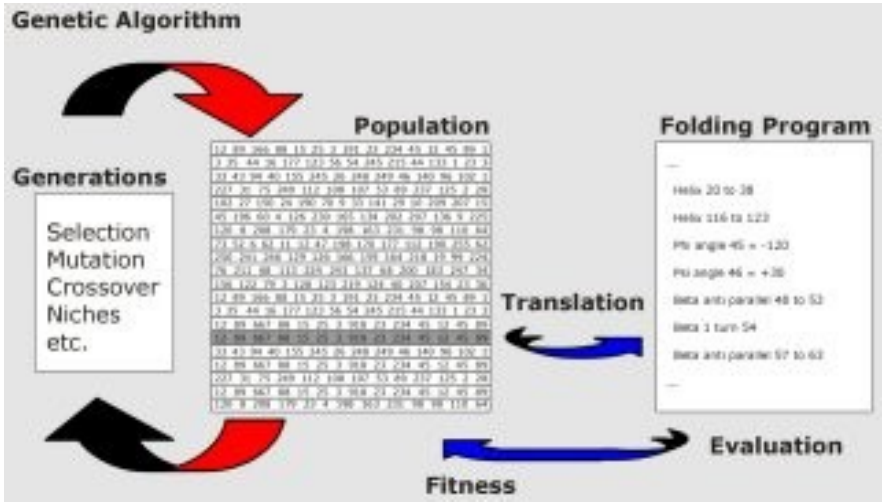


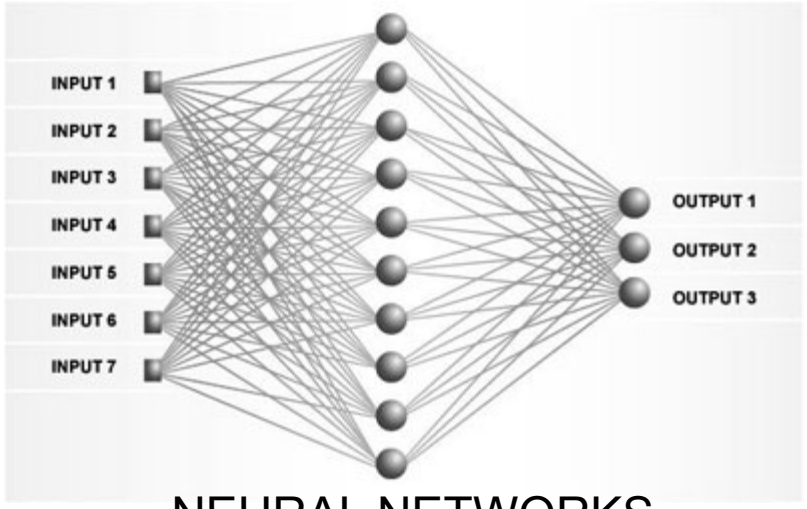
Fig. 1



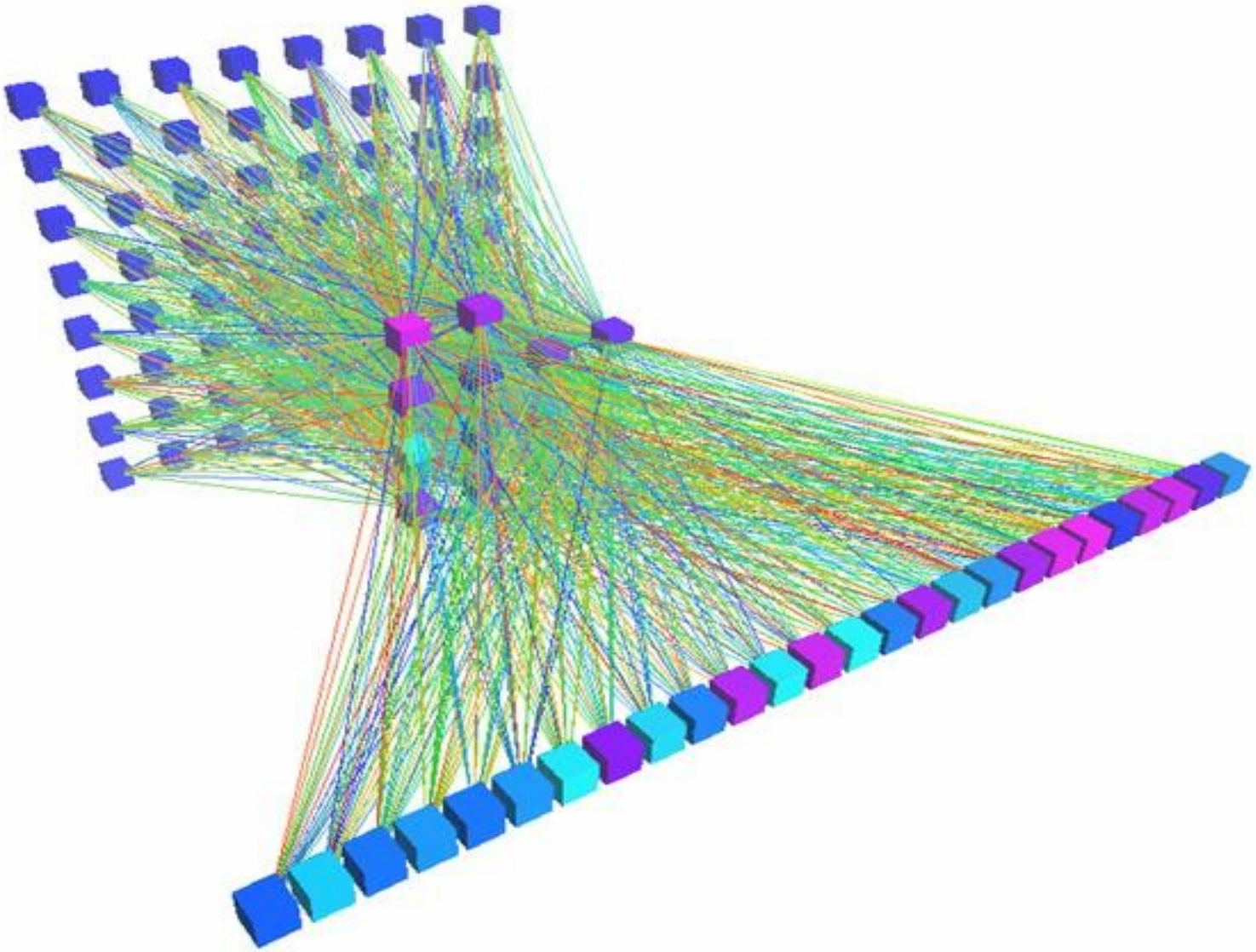
Bayesian networks





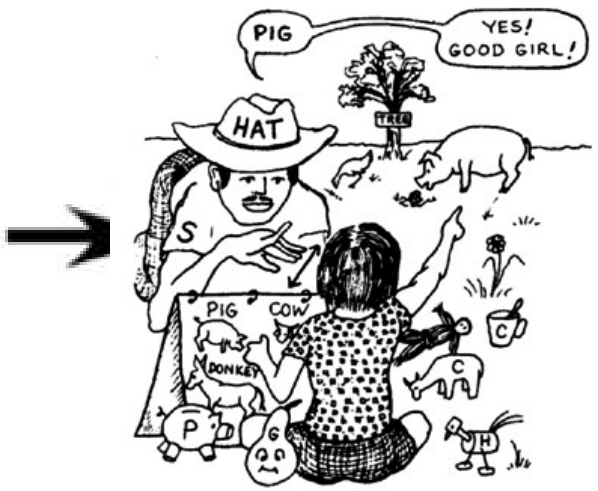


NEURAL NETWORKS



x

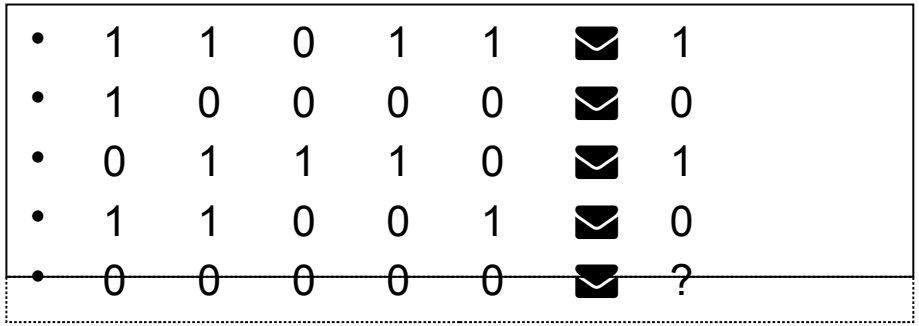
Input#1	Input#2	Input#3
0.9	0.7	0.8
0.0	0.3	0.6
0.4	0.7	0.2
0.2	0.6	0.7
0.6	0.3	0.1
0.8	0.2	0.5
0.2	0.6	0.9
0.2	0.9	0.2
0.4	0.9	0.6
0.3	0.9	0.0
0.7	0.4	0.1
0.4	0.4	0.7
...	...	...
...	...	...
...	...	...
0.3	0.1	0.9



y

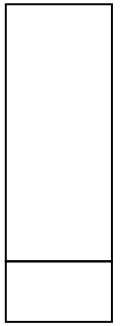
Output
0.5
0.4
0.2
0.1
0.5
0.5
0.7
0.3
0.0
0.1
0.3
0.2
...
...
...
0.9

INPUT DATA

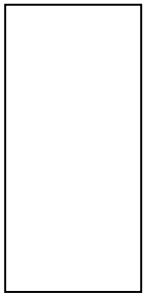


CASE TO BE EXPLAINED

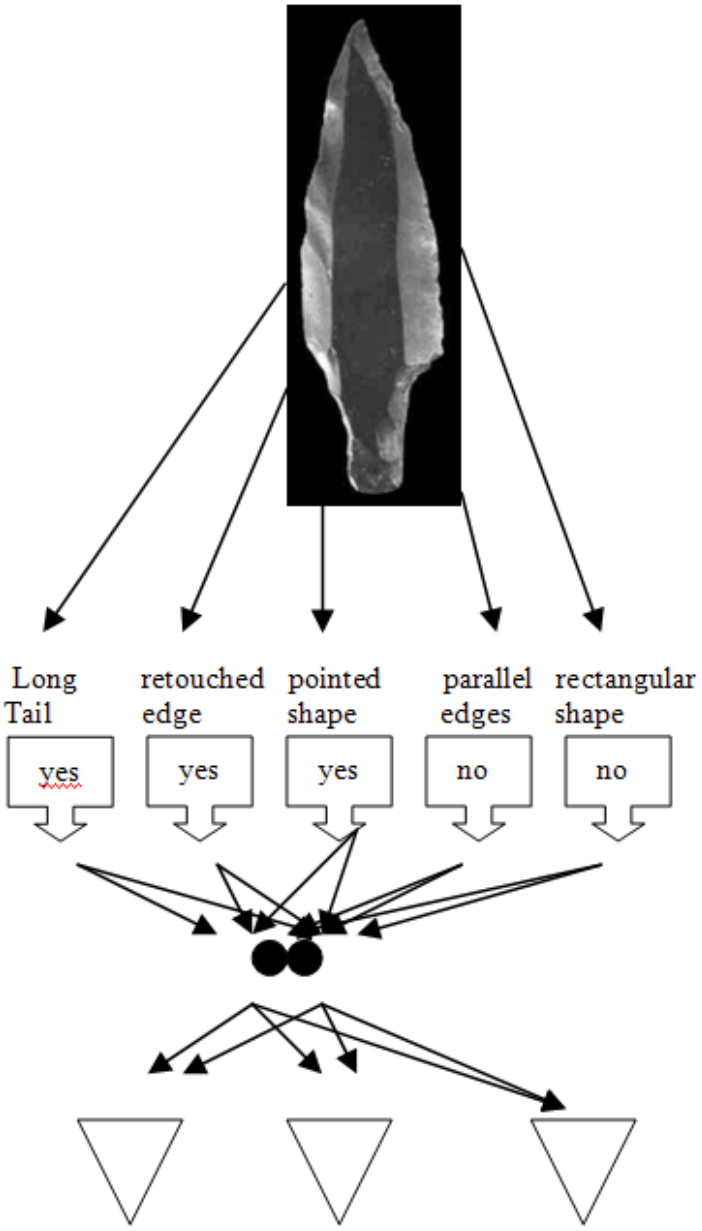
FUNCTION TO BE LEARNT



CONCEPTUAL OUTPUT



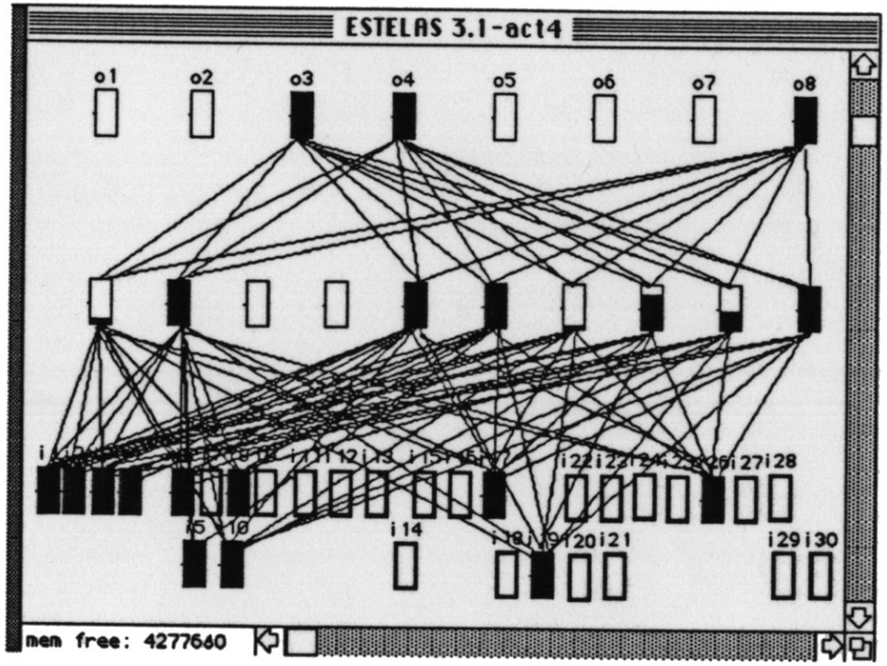
USING THE LEARNED FUNCTION TO EXPLAIN THE UNKNOWN CASE



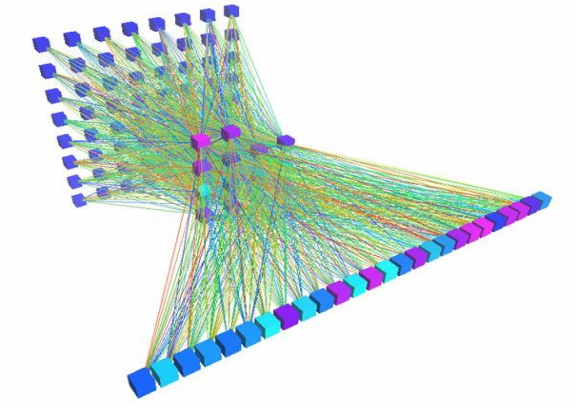
1st. NEURON SUBPOP. (Corresponding to attributes)

2nd. NEURON SUBPOP. (Corresponding to the inner state and connections)

3rd. NEURON SUBPOP. Corresponding to EXPLANATION


ESTELAS 3.1-act4
o1
o2
o3
o4
o5
o6
o7
o8
i14
i29 i30
mem free: 4277660

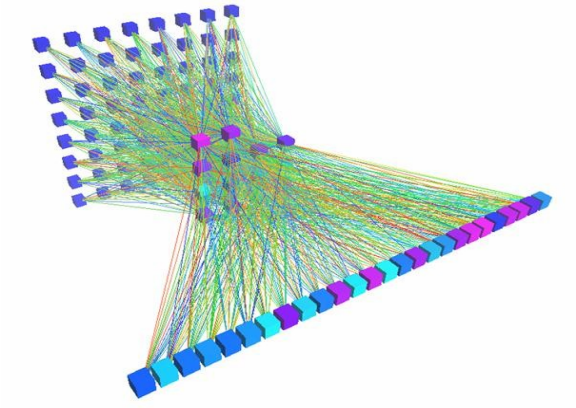
Archaeological functional types: OUTPUT



INPUT: Compositional vectors

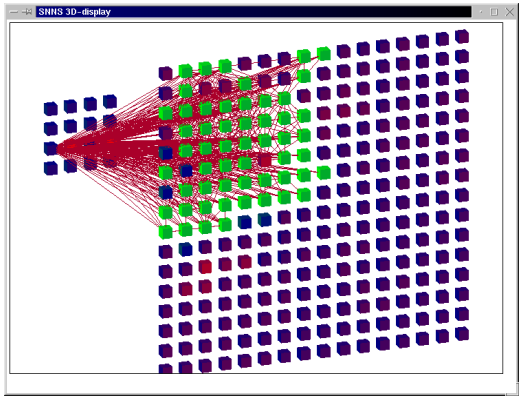
BELL,S., CROSON,C., 1998, “Artificial Neural Networks as a tool for Archaeological Data Analysis”. *Archeometry* 40 (1), pp. 139-151.

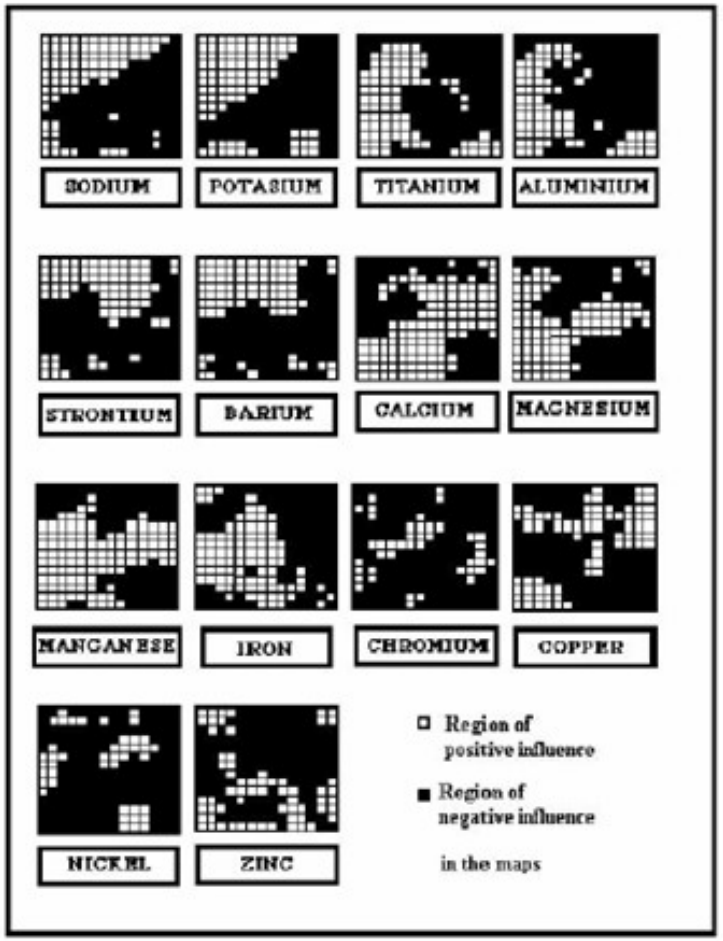
Geographical areas, quarries, provenience sites, woskshops: OUTPUT



INPUT: Compositional vectors

FULCHER, J., 1997, Neural Networks for archaeological provenancing. *Handbook of Neural Computation.* Edited by E. Fiesler and R. Beale. Institute of Physics/Oxford University Press.

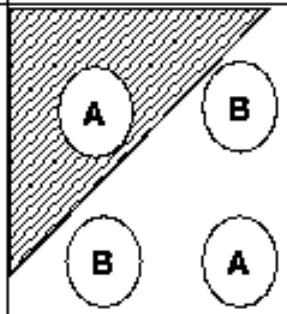
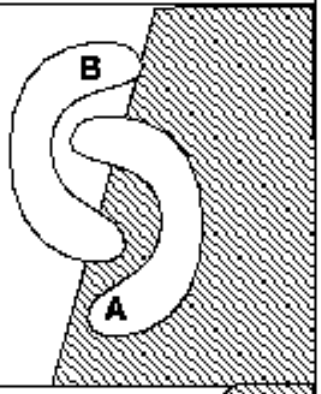
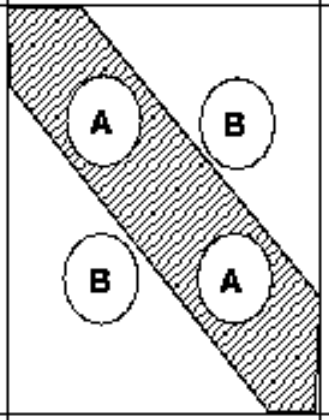
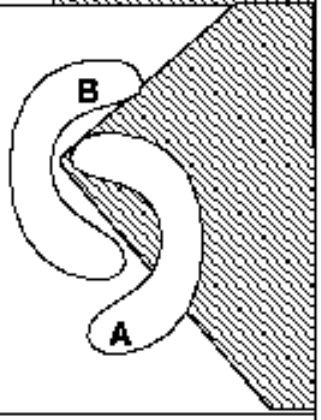
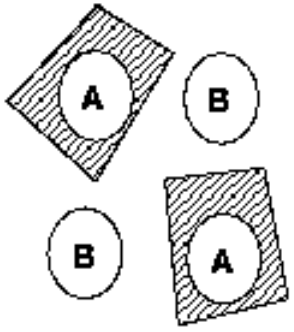
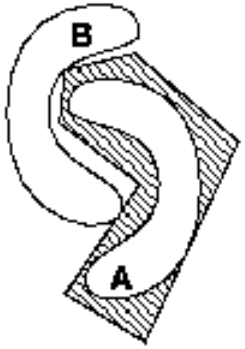




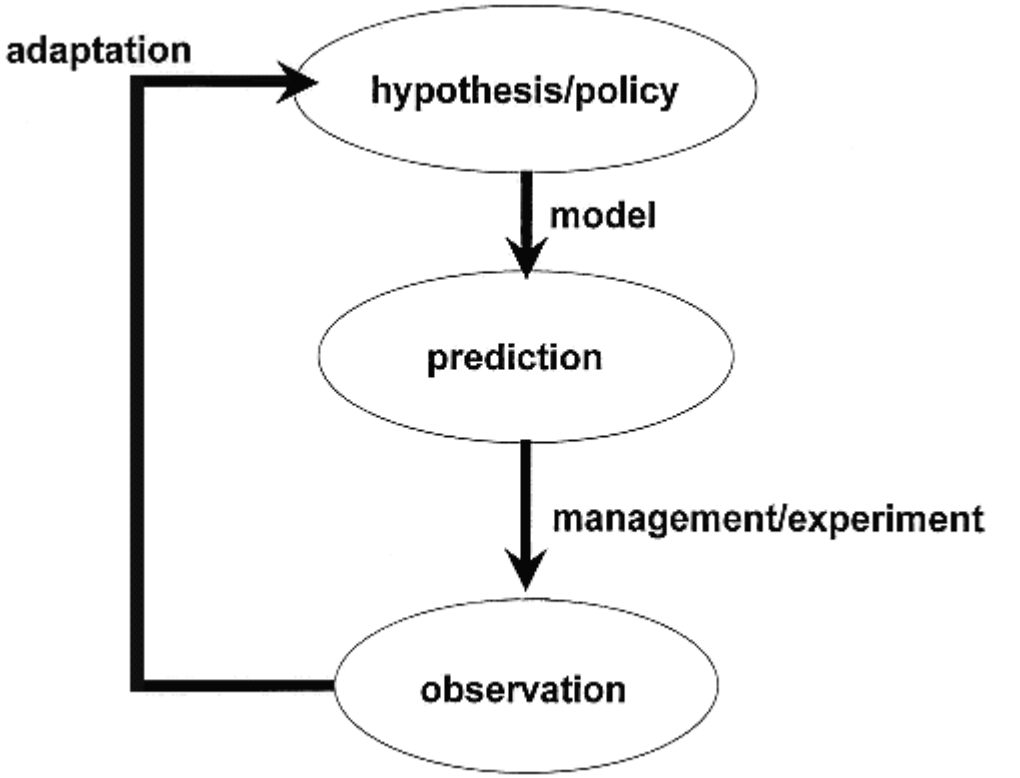
Fourteen 14x14 neuron weight maps reflecting the concentration level of each element.
White neurons reflect high concentration in the elements. Shaded neurons reflect a low concentration.

LOPEZ MOLINERO, A., CASTRO,A., PINO,J., PEREZ-ARANTEGUI, J., CASTILLO, J.R., 2000, "Classification of Ancient Roman Glazed Ceramics using the neural network of self-organizing maps" ***Fresenius Journal of Analytical Chemistry*** **367: 586-589.**

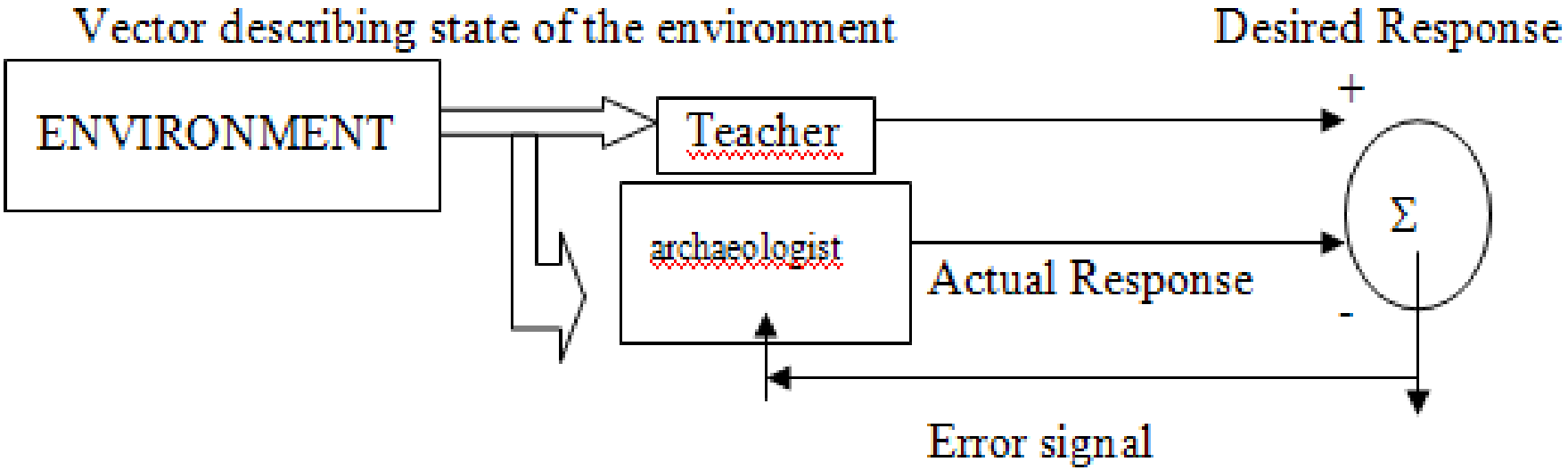
This is not “numerical classification”

Structure	Regions	XOR	Meshed regions
single layer 	Half plane bounded by hyper-plane		
two layer 	Convex open or closed regions		
three layer 	Arbitrary (limited by # of nodes)		

Machine Learning. Adaptive Algorithms



MACHINE LEARNING



The idea is to acquire general concepts from specific training examples. Training examples are instances, which either belong to a special concept, and therefore are positive examples, or do not belong to the concept, and therefore are negative examples.

HISTORICAL PREDICTABILITY:

The idea of prediction comes from the fact that a problem will be considered to have been successfully solved if we are able to produce correct behavioral associations for test items in the majority of cases.

Given a collection of examples of **f***, learn a function* **h** *that* predicts the values of **f**

Learning/ Concept Discovery → as search

To be able to generalize and specialize in a stepwise manner, it is necessary to find minimally more general / specific hypotheses to a given hypothesis. If the hypothesis space is ordered according to generality, learning can be considered as search either from the most general to the most specific hypotheses (top-down) or from the most specific to the most general (bottom-up)

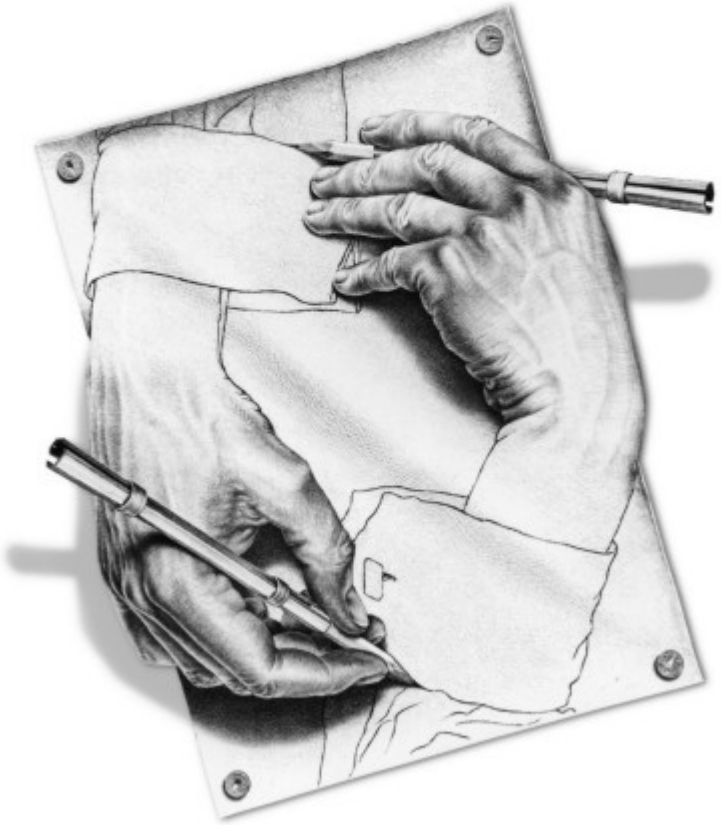
Learning as search

Given a set of possible hypotheses LH, a concept c' in LH, and a positive example e, not covered by c'. The concept g is the most specific generalization of s according to e, if and only if

- g is strictly more general than c'.
- the concept g covers the example e.
- there is no other concept g` in LH, that is strictly more general than c', covers e, but is strictly more specific than g.

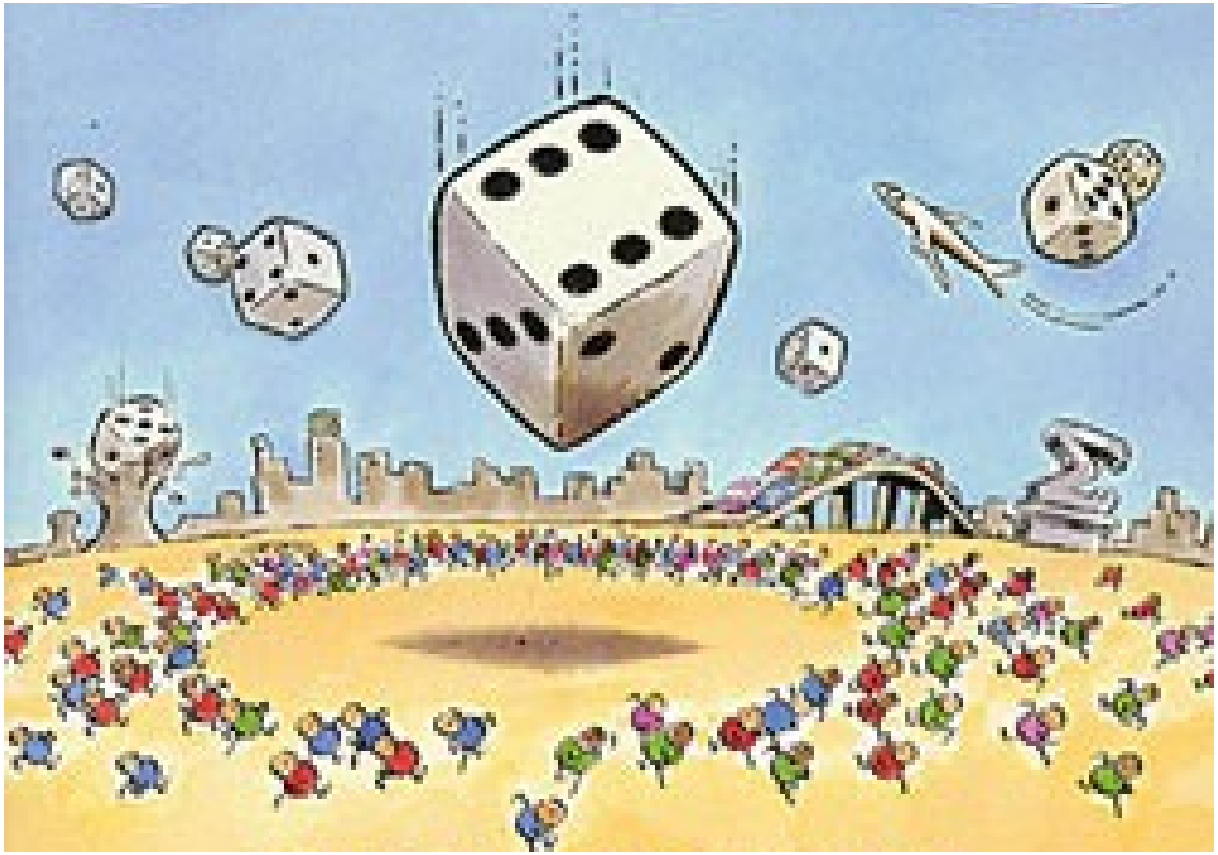
So g is generated by generalizing one step: There is no room left for another generalization g' between g and the recent generalization c'.

The Certainty of Uncertainty



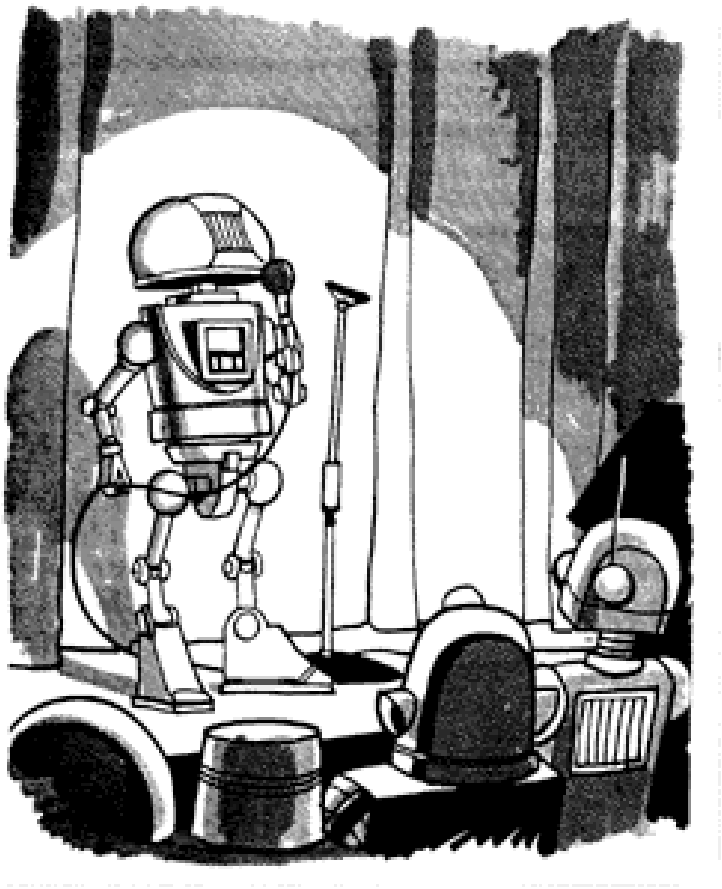
Learning in any scientific circumstance is fast always uncertain because some indeterminacy may appear between actions of human work and the visual and structural properties of the material results of such a work.

The solution of archaeological inverse problems should be approached within a probabilistic framework



At one level, the major task of the system may be described as reducing uncertainty about the knowledge domain.

Computational Philosophy of Science

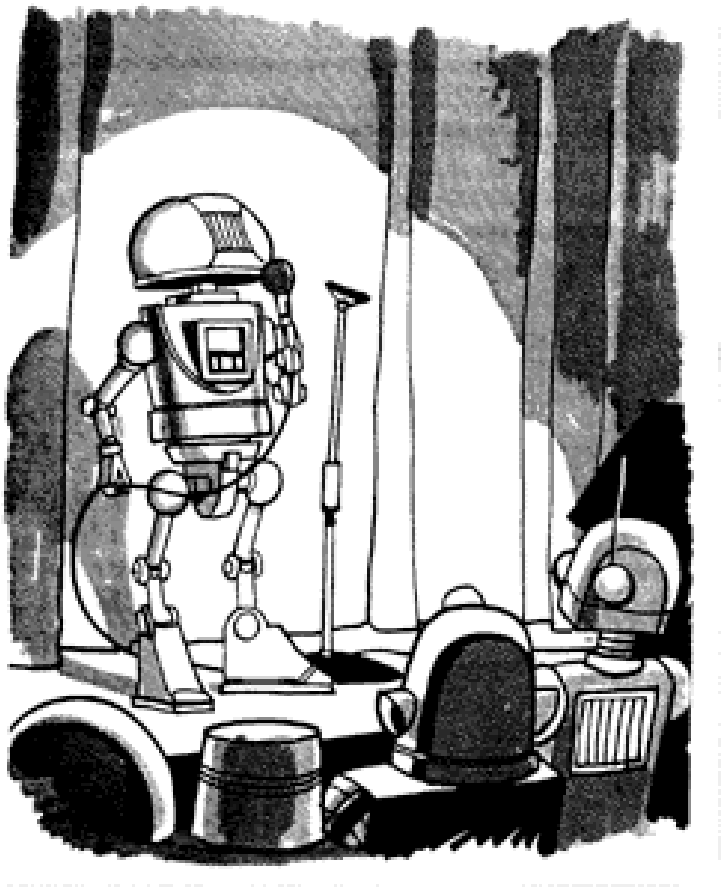


The idea is to design, build and experiment computational systems that perform tasks commonly viewed as intelligent.

The goal is not to simulate intelligence, but to understand real (natural or synthetic) archaeological reasoning by synthesizing them.

The purpose has been to understand how intelligent behaviour in archaeology is possible.

Computational Philosophy of Science



Four capacities are necessary to explain the material consequences of human action in terms of the social actions having produced them. These are:

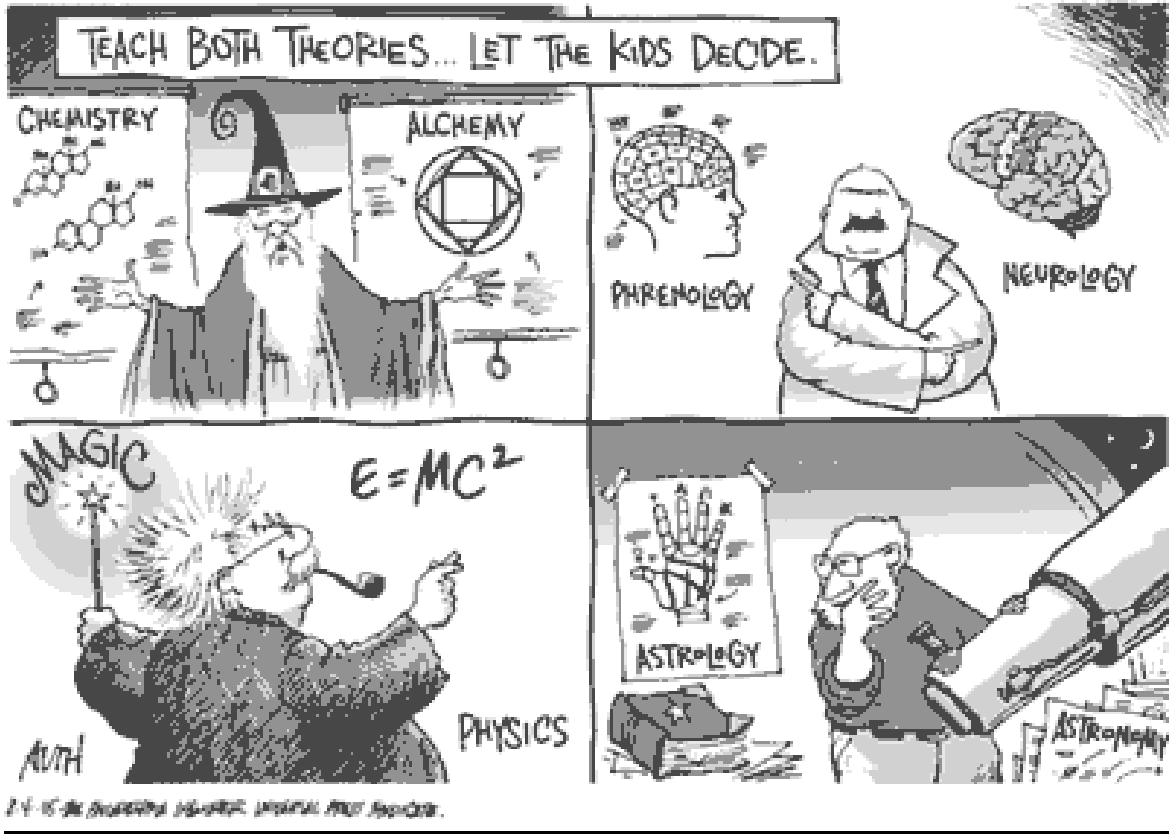
- A basic pattern matching capacity (association)
- A capacity to model the environment (categorization).
- A capacity to physically manipulate real environments (intervention)
- Conscience

The only true POST-modern archaeologist

POST-MODERNISM:

“The worst infectious/contagious mental disease in the history of cognitive methods in science”

(J.A. Barceló, *here and now*)



st-processual
chaeology
ermeneutics, Subjectivity”

or

Explicitly
Scientific
Analysis

?

Predicting the Future

CERRITO,P., 1996, Using Neural Networks To Study And Predict Historical Structure. *Mathematical Connections* Series I, Volume 4. http://www.aug.edu/dvskel/articles.htm

Predicting the Winner

- Seven variables are considered as initial conditions at the start of any rebellion:
-
- **Opponent**: 1=established government is an external force 0=established government is an internal force
- **Ideals**: 2=Republican or democratic government ,1=Dictatorship 0=No plan (or overthrow existing order only)
- **outside pressures**: 1=external force supporting rebels , -1=external force supporting existing order , 0=no external force
- **economic stability of rebels** 2=very strong 1=strong , -1=weak , -2=very weak
- **economic stability of established order:** 2=very strong , 1=strong , -1=weak , -2=very weak
- **Stability of government of rebels:** 2=very strong 1=strong , -1=weak , -2=very weak
- **Stability of government of existing order** 2=very strong, 1=strong, -1=weak , -2=very weak, 1=established government is an external force

SOCIAL SCIENCE EXEMPLES

- output variable:
- Y=1 if the rebellion is successful
- Y=0 otherwise.

SOCIAL SCIENCE EXEMPLES

- The purpose of the analysis is not a classification of social facts as revolutions, but to predict the consequences of social uprisings. As Cerrito explains in her analysis (1996) the Neural network was able to predict the most probable outcome of recent social uprisings (the example of Bosnia, for instance).